Northern
Engineering
and Testing, Inc.

REPORT OF INVESTIGATION
RED LODGE/BEARCREEK
SUBSIDENCE POTENTIAL STUDY

Northern
Engineering and Testing, Inc.

600 South 25th Street
P. O. Box 30615
Billings, MT 59107
(406) 248-9161

October 30, 1987

State of Montana
Department of State Lands
Abandoned Mine Reclamation Bureau
1625 11th Avenue
Helena, Montana 59620

Attention: Mr. Dick Juntunen

Subject: Report of Investigation Red Lodge/Bearcreek
Subsidence Potential Study
Project No. 87-3001.D

Gentlemen:

In accordance with our Professional Services Agreement dated January 1, 1987 and Work Plan dated March 20, 1987 with revisions dated May 19, 1987 and August 31, 1987 we have performed a subsidence potential study for abandoned coal mines in the Red Lodge/Bearcreek area of Montana. The purpose of this study was to identify locations where the potential for subsidence can be considered low, medium or high. We understand this information will be utilized by the Abandoned Mine Reclamation Bureau for determining if a subsidence insurance program is desirable.

The study primarily focused on the potential for subsidence at presently developed locations such as business and residential areas and public roads. The potential for subsidence at adjoining areas which are undeveloped or used for agricultural purposes was considered using empirical relationships rather than analytical prediction techniques.

One relatively shallow (less than 100 feet deep) adit was encountered extending under Highway 308 between Washoe and Bearcreek near the present entrance to the Red Lodge Coal Company. In our Work Plan Revision dated August 31, 1987, we proposed to backfill this adit. A separate report will be submitted detailing our recommendations for backfilling. No other locations of relatively shallow workings were identified beneath presently developed areas.

The analysis we performed considered the following modes of subsidence:

1) Chimney Subsidence
2) Roof Collapse (Beam Theory)
3) Pillar Crushing
4) Pillar Punching

State of Montana
Attn: Mr. Dick Juntunen
Helena, Montana

No single failure mode is favored; the most probable mode changes from one seam or location to another. Our analysis indicates at most locations the critical load condition for modes 2, 3 and 4 occurred while the mines were in operation, because mine dewatering caused roofs and pillars to support saturated overburden while under present conditions most areas support the buoyant weight of overburden. The calculated factor of safety for those failure modes is estimated to have increased by a factor of about 1.7 following closure and aquifer recharge into the mines.

The subsidence potential beneath presently developed areas is generally low. Exceptions to this generalization are identified in the report.

The following report presents the investigations and analysis in detail, and maps in the Appendix show our interpretation of subsidence potentials.

We sincerely appreciate the opportunity to conduct this interesting and challenging study. Should you have any questions regarding this report please contact us at your convenience.

Respectfully submitted,

Larry G. O'Dell

Larry G. O'Dell, P.E.

John M. Pool

John M. Pool, P.E.

LGO/JMP/rmr

TABLE OF CONTENTS

I. INTRODUCTION

The objectives of our work scope were :

1. Develop a subsidence potential map for the town of Red Lodge
2. Prepare plans and specifications for remedial alternatives where shallow workings extend under Highway 308.

During the course of our study these two objectives were modified slightly to limit remedial alternatives to locations where workings under Highway 308 are shallow, and extended the subsidence potential study area to include the Bearcreek area.

The Red Lodge/Bearcreek Project is located in south central Montana. Underground mining began in the 1880's and substantially ceased in the 1930's. A few mines continued operating until the 1950's when virtually all mining ceased.

Within the Red Lodge area a total of seven seams were mined, resulting in multiple extractions beneath much of the area. Detailed mine maps were kept and are now the property of Meridian Minerals Company.

Within the Bearcreek area documentation of mine locations is poorly defined. Although some maps exist, ties to surface reference points were generally not made. Observation of the available maps indicates multiple seam extractions were not made.

A more thorough presentation of the mining history was presented by others (4) in a previous study. Since that subject was not part of our work scope it is not repeated in this report.

II. GENERAL GEOLOGY

The geologic profile in the Red Lodge area typically consists of coarse grained alluvium overlying the Fort Union Formation. The thickness of alluvium is variable, ranging from a few feet to about 100 feet. It consists of gravel, sand, cobbles and boulders. A somewhat similar profile exists in the Bearcreek area except the materials overlying the Fort Union Formation are a combination of colluvium and alluvium and are predominately fine grained sand and clay.

The Fort Union Formation consists of sequences of sandstone, claystone and coal beds. It is locally tilted such that it dips toward the south at angles between 16 to 19 degrees near Red Lodge and at less than 5 degrees in the Bearcreek area.

The average thicknesses and distances between the various coal seams were obtained from cross sections belonging to Meridian Minerals, and are as follows:

Seam No.	Average Thickness, ft.	Depth to Next Seam, ft.
1	9	105
1 1/2	5.5	65
2	8	70
3	10	118
4	10	175
5	8	30
6	6	N/A
Bearcreek	8.5	N/A

Specific conditions at each boring location are described later in this report, and individual boring logs are presented in Appendix A.

III. INVESTIGATIONS

The investigations consisted of the following activities:

- Study of existing mine maps and observation of surficial conditions.
- Subsurface explorations utilizing rotary and coring techniques.
- Borehole photography where practical.

A proposed resistivity survey was not performed after we determined that workings along Highway 308 would likely be deeper than could be reliably detected by that method.

A. Map and Surfacial Conditions Study

Maps of the mines were borrowed from Meridian Minerals. The maps show that room and pillar extraction methods were used. It also appears that pillars were robbed from some areas, probably during retreat. Those maps were used to prepare Drawing Nos. 87-3001.D-1 through 4, in Appendix A, which show the depth of cover and cumulative thickness of coal mined from beneath specific locations. These were then used to create the final subsidence potential maps Drawing Nos. 87-3001.D-5 & 6, showing the ratio of depth of cover to mined thickness. Empirical correlations have been developed (7) which utilize that ratio to approximate the subsidence potential. A preliminary subsidence potential map was prepared to help target general locations for detailed subsurface explorations. Maps of individual seams were then studied to select specific hole locations. Our intent was to intersect rooms or adits, and where multiple seams were mined, to intersect rooms in more than one seam. From mine floor elevations shown on the maps, three cross sections were constructed showing the orientations of mined areas with respect to one another and to the ground surface. These are presented on Drawing No. 87-3001.D-7.

B. Subsurface Explorations

The following seven locations were ultimately selected for subsurface explorations:

- Red Lodge Airport
- Highway 308 just east of Red Lodge
- Red Lodge - 14th Street between Hauser and Main
- Washoe Adit under Highway 308
- Washoe Mine adjacent to Highway 308
- Smith Mine No. 2 Adit under Highway 308
- Smith Mine No. 2 Unmapped Adit under Highway 308

Locations of these borings are shown on the drawings in Appendix A. Drilling was performed by Rock Creek Drilling under the supervision of our personnel. The following paragraphs summarize the conditions encountered at each location. Logs of the borings are presented in Appendix A.

After drilling was complete a video tape was made of the boreholes, where practical. The photography met with varying degrees of success. Two factors limited camera use; 1) water turbidity and 2) an underwater depth limitation of 100 feet.

Red Lodge Area

At the airport, DH-1 intersected both the No. 1 1/2 and No. 2 Seams. While approaching the No. 1 1/2 Seam evidence of roof strain and possible collapse began to appear below 117.5 feet and continued down to the coal at 129 feet. The No. 1 1/2 Seam is between 129 and 134 feet; it is highly fractured. We interpret the zone between 117.5 to 129 to be fractures opened by roof collapse. The entire thickness of the coal was present, as shown by the video tape. This indicates a pillar rather than a room was intersected.

The hole continued down to the No. 2 Seam near 204 feet. The rate of drill penetration increased below 200, feet but the video tape does not show a change in the rock. A definite void is present between 204 and 209 feet; then about seven feet of soft broken material is present before the mine floor is encountered. The camera could not progress deeper than 209 feet due to the broken rock. The rubble is interpreted to be roof fall material. The No. 2 Seam averages eight feet thick so it appears roof collapse has progressed only about four feet above the original roof. The increased rate of drill penetration below 200 feet might indicate a weakening of the rock, but it could not be detected by the camera.

On the east bench DH-2 was drilled in an area where mine maps show the No. 1 1/2 Seam was extensively robbed of pillars. This location was selected for the purpose of determining how far upward roof collapse might extend, for comparison with empirical correlations. Our depth of cover map predicted the floor to be close to 350 feet. Continuous coring began at 310 feet and continued to 360 feet. Evidence of roof strain and collapse was noted in the core beginning about 326 feet, where open joints began to appear. Some loss of circulation was encountered but no distinct voids detected. Recovery was good and RQD was high throughout the cored interval. Only a two or three foot interval near 345 feet produced highly broken rock. This suggests total convergence of roof and floor has occurred at this location. A

thin layer of coal and partial circulation loss near 358 feet is interpreted to be the mine floor. The hole was continued down to 370 feet with a tricone rotary bit with no additional evidence of collapse or open joints noted below 360 feet. Turbidity and the camera's depth limitation limited photography to a depth of only 175 feet. Within that depth no evidence of subsidence was noted although several fractured and eroded zones are evident.

On 14th Street, DH-3 encountered a pillar in the No. 4 Seam between about 228 and 237 feet. The core from that interval consists of highly fractured coal. The fracturing was so extensive that laboratory strength tests were not possible. Core recovery above the coal was good; about 95 percent with an RQD of 85 percent, indicating the roof to be relatively intact.

The boring was continued down to intersect the No. 5 Seam near 435 feet. A distinct void was not encountered, but roof strain was evident in the core below 425 feet. Absence of coal in the core verifies that a former room was intersected. Since neither a distinct void nor a significant thickness of rubble was detected, we believe there has been roof-floor convergence, probably due to pillar crushing or punching. The roof strain noted in the core suggests pillar crushing or punching has caused the roof to sag. Borehole photography was not performed due to the camera's underwater depth limitation.

Washoe and Smith Mines

A total of four borings were originally planned at these two sites. Two borings (DH-5 and 6) were made at the Washoe Mine near the locations proposed in our Field Investigation Plan dated May 19,1987. The holes extended to depths of about 250 and 265 feet. DH-5 attempted to intersect the sloped entry but missed and DH-6 intersected a pillar. In both borings about eight feet of coal was encountered very close to the depths predicted by our depth of cover map. Based upon projections of mine map elevations the Washoe sloped entry should be about 200 feet below Highway 308. Neither boring encountered any evidence to suggest subsidence.

At the Smith Mine, two borings (DH-7 and 8) were planned to intersect adits under Highway 308. West of the present Red Lodge Coal Company entrance two sags are evident in the pavement surface and correspond to mapped adit locations. At this location three holes (DH-7,7A and 7B) were drilled attempting to intersect an adit. All three borings encountered a similar profile which we interpret to be fill to about 16 feet, then coal and bedrock. It appears the adits were exposed and backfilled during highway construction. The sags most likely represent differential settlement between the fill and natural materials.

East of the Red Lodge Coal Company entrance an adit not shown on the mine maps exists; it is shown on the Montana Highway Department construction drawings where it is identified as a mine shaft. Two drill holes (DH-8 and 9) were required to intersect this adit. The roof is at a depth of 57.8 feet and a void about 9 feet high is present. About seven feet of well cemented sandstone forms the roof. Photography of this hole showed no evidence of roof strain nor was rubble observed on the floor. Turbidity limited sight distance to about one foot so no attempt was made to view in a horizontal direction.

C. Laboratory Testing

Approximately 93 percent of the 154 feet of rock cored was recovered. The following laboratory testing program was preformed to obtain representative material properties for analytical analysis.

Drill Hole No.	Sample Depth, ft.	Unconfined Compression	Splitting Tensile Strength	Unit Weight and Moisture Content
1	123.0 - 124.0		X	X
1	135.0 - 136.0	X		X
1	136.0 - 137.0	X		X
2	311.2 - 312.0			X
2	317.0 - 317.8			X
2	333.4 - 334.1			X
2	344.8 - 345.5			X
2	352.5 - 353.3			X
3	212.0 - 213.0	X		X
3	213.0 - 214.0		X	X
3	225.4 - 226.3	X		X
3	227.6 - 228.3		X	X
3	414.0 - 414.7	X		X
3	414.7 - 415.1		X	X
3	441.2 - 442.0	X		X
N/A	Coal	X		X
N/A	Coal	X		X
	Totals:	8	4	17

None of the coal recovered from the drill holes produced samples of sufficient size for laboratory strength tests. Several pieces of coal were provided by the Red Lodge Coal Company, which we understand originated from the Smith No. 2 Seam. From these we were successful in cutting two cubes for compressive strength tests.

Although ASTM D2938 does not require recording axial deformation for unconfined compression of rock cores, we recorded that information so that an approximation of the elastic modulus could be calculated. Plots of these tests are shown on Plates 1 through 6 in Appendix A. The table on page 6 summarizes all of the test results.

IV. ANALYSIS

Having reviewed relevant literature and in consideration of the subsurface conditions encountered, we selected the following methods for analyzing the various failure modes:

Northern
Engineering and Testing, Inc.

SUMMARY OF LABORATORY TEST RESULTS

RED LODGE/BEARCREEK SUBSIDENCE STUDY
RED LODGE, MONTANA

Drill Hole No.	Depth in Feet	Classification	Unconfined Compressive Strength, (Q_u), ksf	Splitting Tensile Strength, (Q_t), ksf	Dry Unit Weight, pcf	Moisture Content, %	Modules of Elasticity (E), psi
DH-1	123.0-124.0	Claystone		50	142	5	
	135.0-136.0	Sandstone	470		146	4	3.5×10^5
	136.0-137.0	Sandstone	350		147	4	4.2×10^5
DH-2	311.2-312.0	Sandstone			145	3	
	317.0-317.8	Sandstone			150	2	
	333.4-334.1	Sandstone			147	2	
	344.8-345.5	Claystone			147	3	
	352.5-353.3	Sandstone			142	2	
DH-3	212.0-213.0	Claystone	1020		152	2	9.6×10^5
	213.0-214.0	Claystone		98	153	3	
	225.4-226.3	Claystone	720		151	2	6.9×10^5
	227.6-228.3	Claystone		82	151	2	
	414.0-414.7	Sandstone	410		138	5	4.5×10^5
	414.7-415.1	Sandstone		69	145	2	
	441.2-442.0	Sandstone	1000		151	2	1.0×10^6
N/A	N/A	Smith No. 2 Coal	401		74	11	
N/A	N/A	Smith No. 2 Coal	310		74	10	

Failure Mode	Method and Source
Chimney Subsidence	Empirical: Karfakis; Subsidence over Abandoned Coal Mines
Roof Collapse	Analytical: Wright; Roof Control Through Beam Action and Arching
Pillar Crushing	Analytical: Bieniawski; Rock Mechanics Design in Mining and Tunneling
Pillar Punching	Analytical: Rockaway and Stephenson; Support of Coal Pillars

Based on a series of assumed mine room failures, the predicted geometry of "trough" shaped subsidence features was estimated using methods presented by Peng; Coal Mine Ground Control. That calculation was developed for use in longwall rather than room and pillar extractions, but it is considered a reasonable approximation for complete roof-floor convergence from any failure mode which does not create significant bulking.

The geometry of this coal field includes two aspects not normally considered in most analytical models: 1) multiple seam extractions and 2) inclined beds. The following discussions of the various failure modes include a description of how we considered those two geometric aspects.

In the interest of brevity, the results of our observations and analysis are summarized first, followed by detailed discussions. The summary statements apply equally for the Red Lodge and Bearcreek areas.

Failure Mode	Summary of Analysis
1. Chimney Subsidence	a. Appears to be the mode responsible for previous subsidence features. b. Only the Bill Palmer property east of Red Lodge, a small area west of the end of 10th Street, and two small areas in the Bearcreek area are considered to have a high potential for future chimney subsidence.
2. Roof Collapse	a. Evidence of roof strain observed in the drill holes is limited to within 20 feet or less of the predicted mine roof elevations. b. Calculations indicate the potential for massive roof collapse to be low. c. Using the beam analysis, the roof of Seam No. 5 is calculated to fail about 15 feet above the mine roof, where a competent layer capable of bridging the span was encountered. The other seams were predicted to have very little roof failure.

d. For most of the seams, the critical load condition for roof collapse, pillar crushing and pillar punching was during mining because subsequent mine flooding has reduced overburden pressures from saturated to buoyant conditions.

3. Pillar Crushing
   a. Calculations indicate that beneath presently developed areas future pillar crushing is not likely.
   b. Mines extended deeper than calculations predict pillars should have supported; indicating the coal might be stronger than tests indicate.

4. Pillar Punching
   a. Pillars are not predicted to punch more than one or two feet, due to underlying competent material.
   b. A short punch distance could initiate the limited roof collapse observed in the borings.

A. Chimney Subsidence

Chimney subsidence is one form of roof collapse. It is a progressive upward movement of a void. This failure mode is favored where rock units are thinly bedded. The thin beds constitute thin beams spanning across a void. The collapse of one reduces support for the one above it.

Figure 1 on page 9 shows the three outcomes of chimney subsidence; it can be arrested by a competent layer, by bulking or form a sinkhole at the surface. For this analysis it is assumed that caving will not be arrested by a competent layer; that is considered in the roof collapse discussion. As illustrated in Figure 1 the collapsed material contains voids and therefore occupies a greater volume than the intact material. Given a sufficient overburden thickness this bulking can effectively fill the void. Figure 2 presents heights of caving ratios for various void geometries and bulking factors. A bulking factor in the range of 0.2 has been inferred as an average value for western coal fields from observations by others(2 & 3). Using that value the maximum height of collapse for this mode is in the range of 5 to 15 times the mined seam thickness, for horizontal seams. For the case of a dipping seam it is possible for conical and elliptical chimneys to progress farther. Those two geometries involve limited areas rather than entire rooms. As a result a sloping floor allows material to initially roll away from the collapse location, so a larger area of the room fills with collapsed material before bulking can begin to fill the immediate chimney location. The additional volume of material cannot be easily quantified because it is a function of several variables including horizontal dimensions of the chimney, floor inclination, and location within the room. For the worst case conditions our calculation indicates the volume of additional material flowing out into an inclined room can be about twice that for a horizontal room. Consequently, for worst case conditions, it is possible for conical and elliptical chimneys having small horizontal dimensions to progress nearly twice as far as indicated by Figure 2. However, small chimneys are more prone to being arrested by a more competent layer and therefore rarely reach the surface.

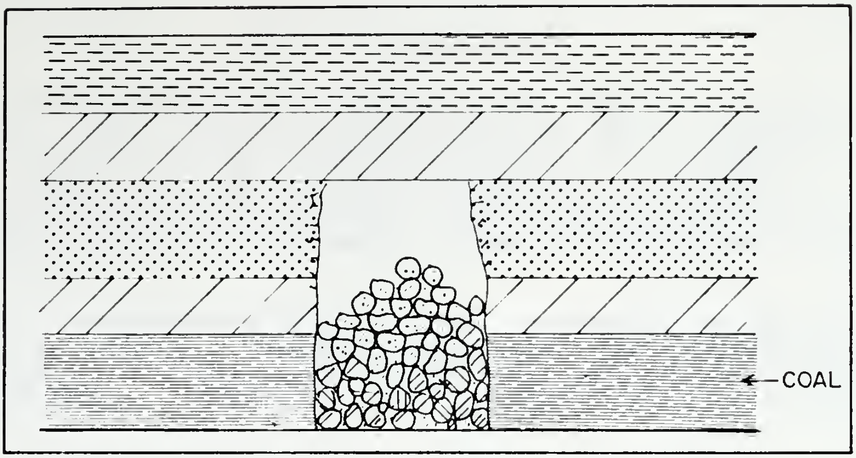


Figure 1a Caving Arrested by a Competent Stratum

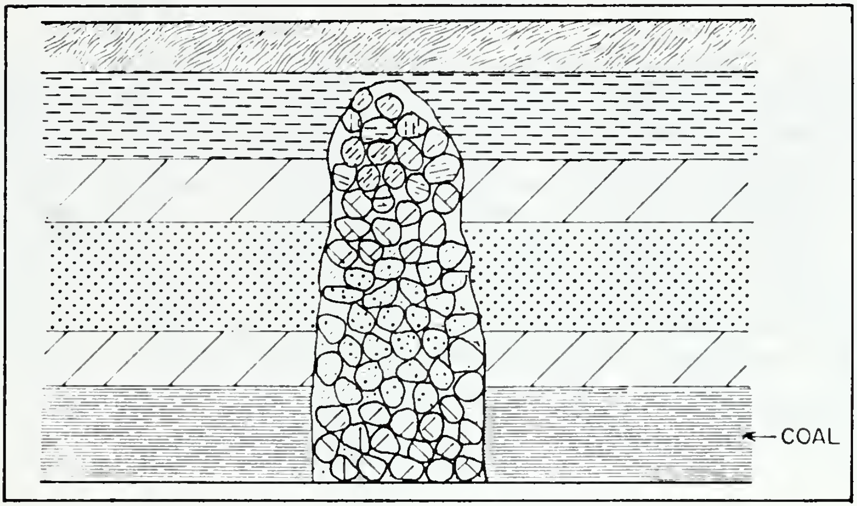


Figure 1b Arrested by Bulking of Roof Debris

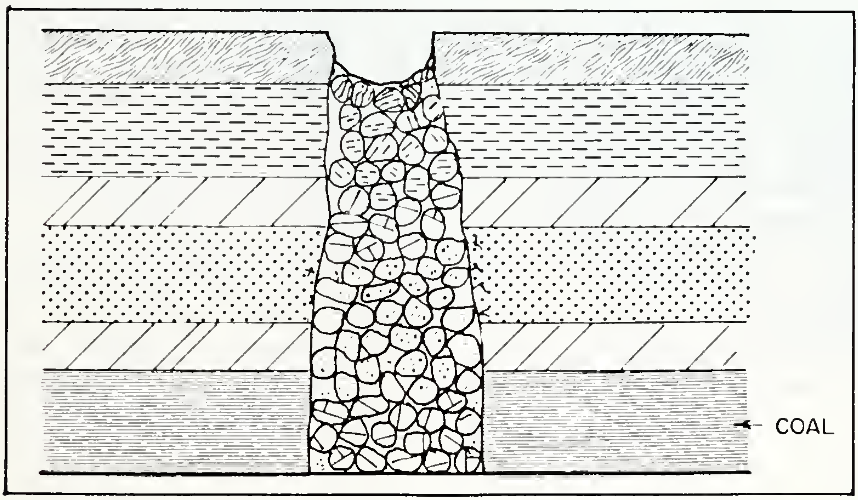


Figure 1c. Formation of a Sinkhole at the Surface

Figure 1 Chimney Subsidence Development

DH-2 was intentionally located where maps show extensive pillar robbing. For that area, we would expect the prism geometry of chimney subsidence to most accurately represent the height for collapse to progress. From the condition of the core and projected mine roof elevation, it appears the height of collapse was limited to 20 feet or less. Based on an average seam thickness of 5.5 feet, Figure 2. suggests a bulking factor in the range of 0.3 for that area.

In consideration of the conditions encountered in DH-2 and other borings, along with the special circumstances that could allow conical and elliptical chimneys to propagate farther than indicated by Figure 2, we selected the following criteria to assign subsidence potential:

Overburden to Mined Thickness Ratio	Subsidence Potential
10:1 or less	High
10:1 to 20:1	Moderate
Greater than 20:1	Low

To consider the influence of multiple seams, one begins with an assumed chimney in the deepest seam. If the distance from that seam up to the next is greater than the predicted collapse height, then that lowest seam can be removed from further consideration. If the contrary is true the upward progression can continue. Iterations continue using the summation of mined thicknesses and separations between seams. Using the cross sections shown on Drawing No. 87-3001.D-7 the following conclusion can be made regarding multiple seam chimney subsidence. The only locations where the potential for future chimney subsidence is considered high are on the Bill Palmer property east of Red Lodge, a small area west of the end of 10th Street in Red Lodge, and where adits are shallow in the Bearcreek area. Those areas are shown on the subsidence potential map as having a high potential for future subsidence. Two small areas within the town and part of the runway classify as having a moderate subsidence potential. A reduction of the Red Lodge Subsidence Potential map is presented on page 12.

B. Roof Collapse

The mechanism of mine roof collapse is simply a large scale version of chimney subsidence. The concept of the theory is illustrated in Figure 3. The rock layers above the mine are analyzed as a series of beams. Beam thickness is dependent upon thickness of major rock types or bedding or discontinunity characteristics. Each beam is assigned a unit weight, tensile strength and elastic modulus. Initally calculations are made to estimate the deflection of each beam for determining if beams act independently or as composites. In a system of several beams both independent and composite beams can exist in the profile. A sample calculation is presented in Appendix B along with results of specific cases analyzed. Profiles at specific hole locations were modeled using three or four beams. The first beam consisted of the alluvium, having weight but contributing no strength. Subsequent beam dimensions and material properties were selected based upon the log of each hole and laboratory test results. The idealized profiles and material properties analyzed are presented in Figure 4.

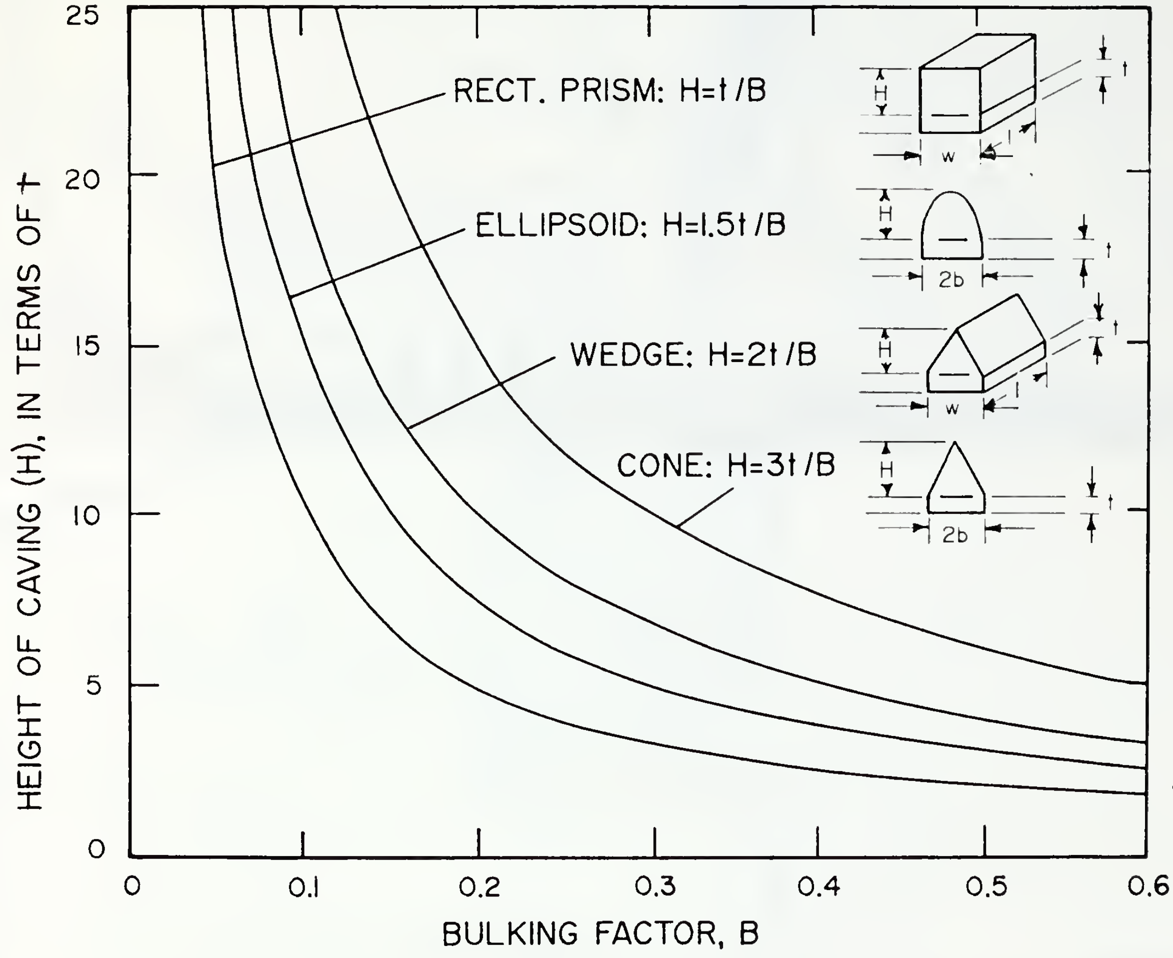
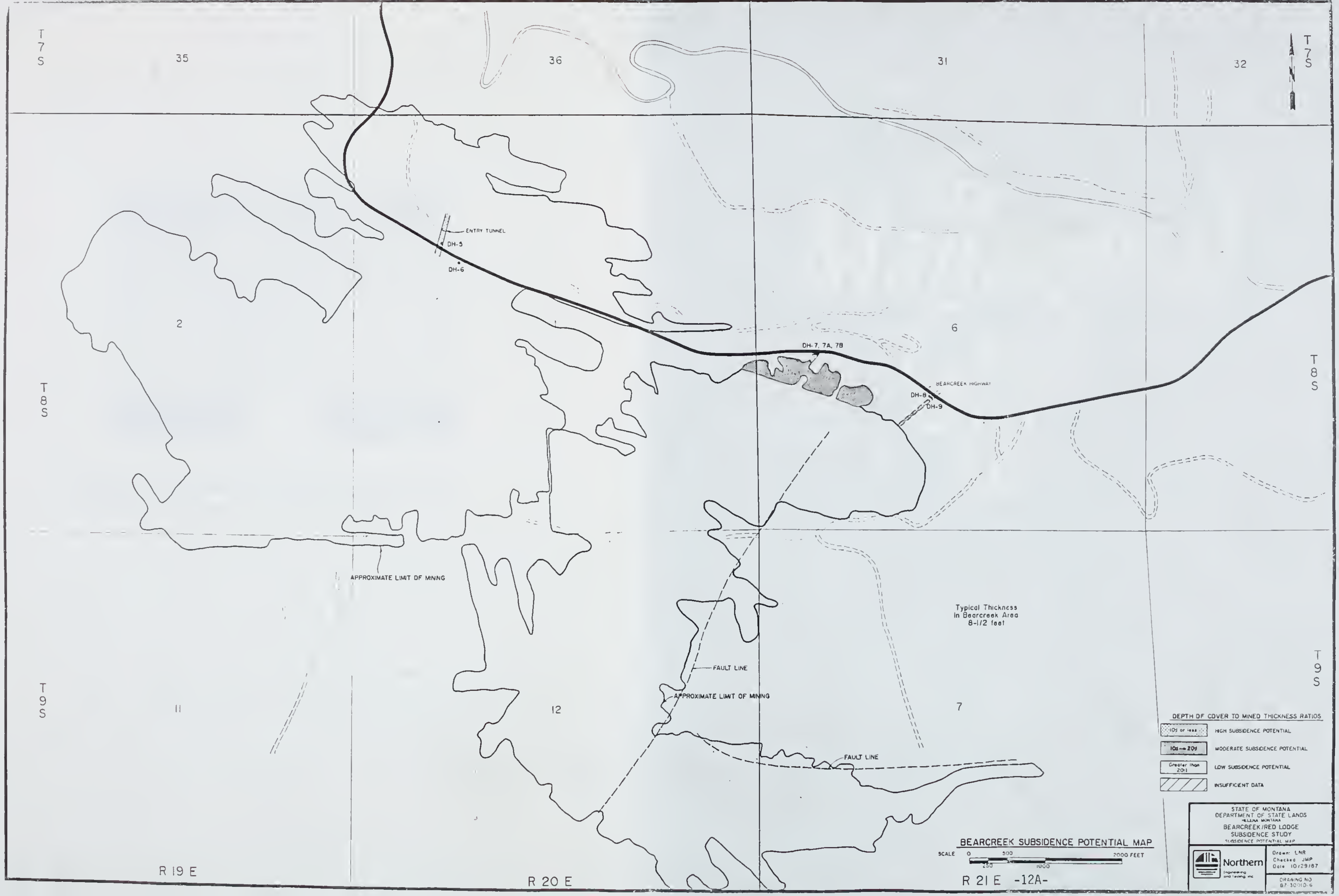


Figure 2 Maximum Height of Stoping

(from Karfakis)


APPROXIMATE LIMIT OF MINING
26
25
DH-1
DH-3
DH-2
BEARCREEK
T 7 S
34
35
36
APPROXIMATE LIMIT OF MINING
DEPTH OF COVER TO MINED THICKNESS RATIOS
10:1 or less
HIGH SUBSIDENCE POTENTIAL
10:1 → 20:1
MODERATE SUBSIDENCE POTENTIAL
Greater than 20:1
LOW SUBSIDENCE POTENTIAL
INSUFFICIENT DATA
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA, MONTANA
RED LODGE / BEARCREEK
SUBSIDENCE STUDY
SUBSIDENCE POTENTIAL MAP
Northern
Drawn: LNR
Checked: JMP
Date: 10/29/87
DRAWING NO.
87-300LD-3
RED LODGE SUBSIDENCE POTENTIAL MAP
SCALE 0 250 500 1000 2000 FEET
R 20 E


T 7 S
35
36
31
32
T 7 S
ENTRY TUNNEL
DH-5
DH-6
2
6
DH-7, 7A, 7B
BEARCREEK HIGHWAY
DH-8
DH-9
T 8 S
T 8 S
APPROXIMATE LIMIT OF MINING
Typical Thickness
In Bearcreek Area
8-1/2 feet
FAULT LINE
APPROXIMATE LIMIT OF MINING
FAULT LINE
T 9 S
11
12
7
T 9 S
DEPTH OF COVER TO MINED THICKNESS RATIOS
10:1 or less
HIGH SUBSIDENCE POTENTIAL
10:1 — 20:1
MODERATE SUBSIDENCE POTENTIAL
Greater than 20:1
LOW SUBSIDENCE POTENTIAL
INSUFFICIENT DATA
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA MONTANA
BEARCREEK/RED LODGE
SUBSIDENCE STUDY
SUBSIDENCE POTENTIAL MAP
Northern
Engineering and Testing, Inc
Drawn: LNR
Checked JMP
Date 10/29/87
DRAWING NO
87-30010-6
BEARCREEK SUBSIDENCE POTENTIAL MAP
SCALE 0 250 500 1000 2000 FEET
R 19 E
R 20 E
R 21 E

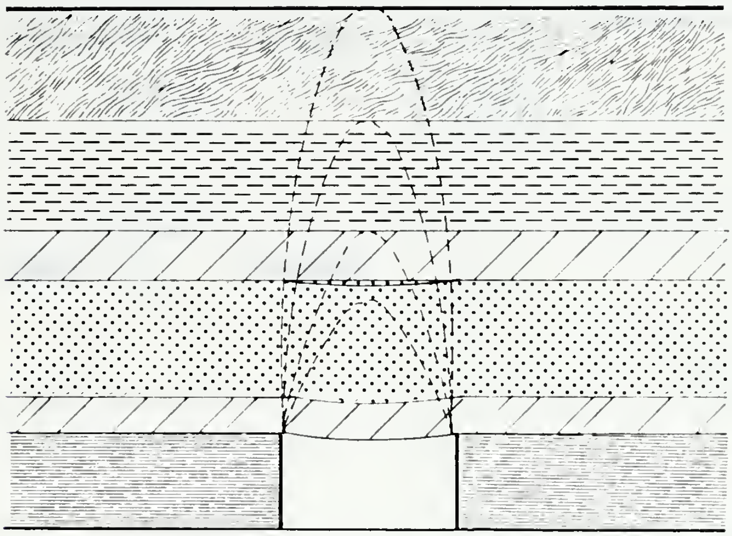
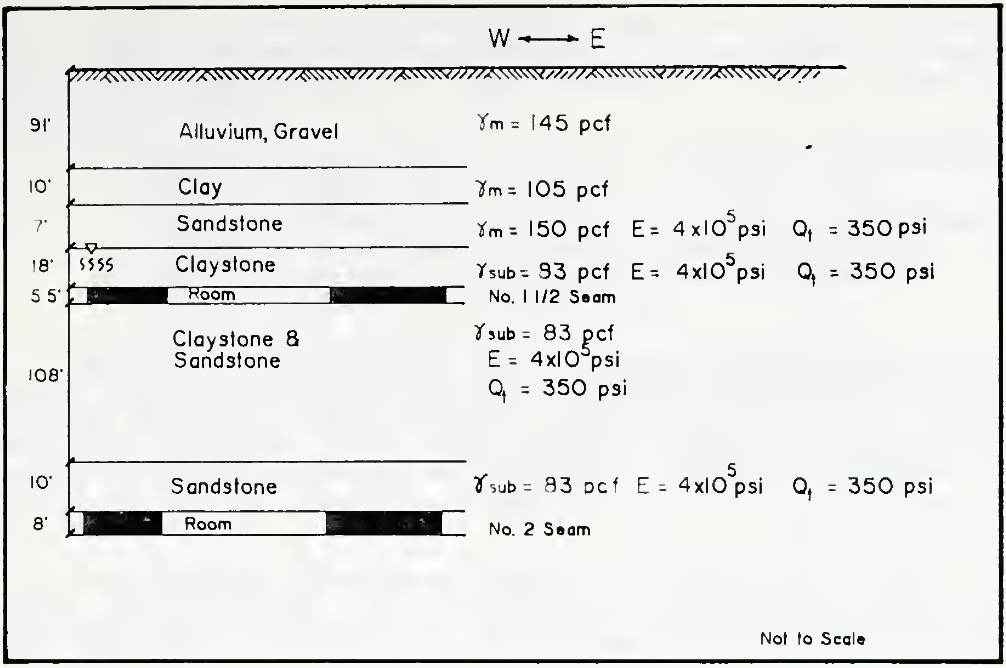
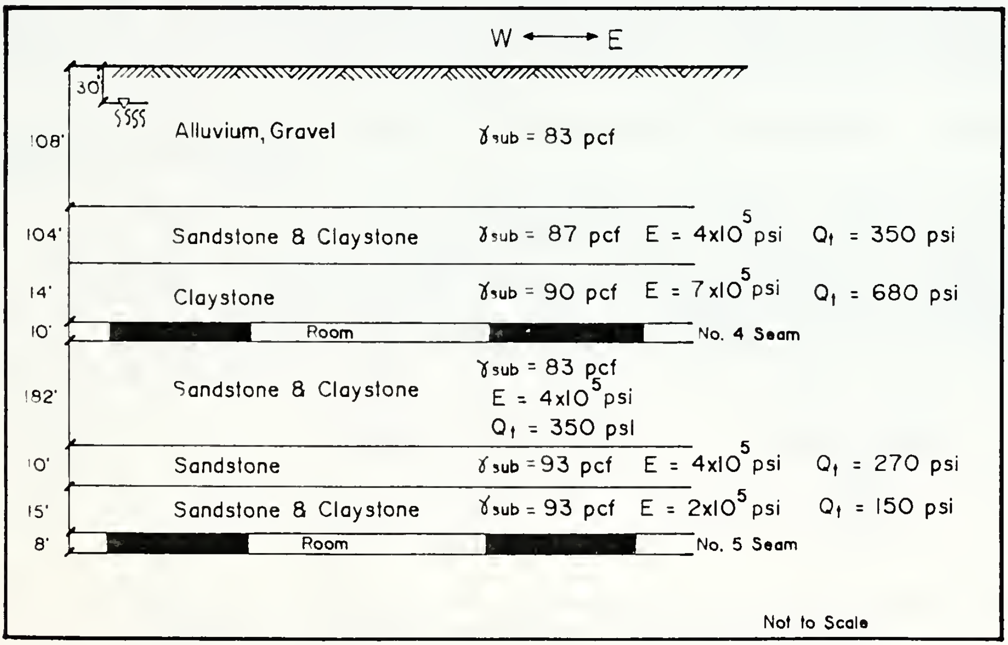


Figure 3 Deflection of the Roof Beams, Bed Separation, and Roof Stress Variation.

Figure 3. Deflection of the [illegible] Data Interpolation, and Root Stress Variation



4a. DH-1, No. 1-1/2 & No. 2 Seams



4b. DH-3, No. 4 & No. 5 Seams

Figure 4 - Profiles for Roof Collapse Analysis

After an initial calculation was made the input variables were modified to check the analysis for sensitivity to variations in material properties, mine room widths and beam thickness. From this exercise we determined the following:

- The calculated safety factor is inversely proportional to changes in unit weights.
- The calculated safety factor is directly proportional to changes in beam thickness, tensile strength and modulus.
- Variations in room width have an inverse exponential ($1/x^2$) effect on the calculated safety factor.

The unit weight of materials will vary dramatically depending upon groundwater levels and assumptions made regarding hydrostatic conditions. During mining the rooms were dewatered so the saturated unit weight of overburden was supported. After the mines were closed, those portions which are flooded now support the buoyant unit weight of submerged overburden. This change in unit weights generally increases the calculated safety factor by a factor of about 1.7.

The condition of dipping seams was determined to have little influence on the calculated safety factors. To analyze the condition of multiple extractions, only the rock units between the openings were considered in the beam strength.

In order to analyze a variety of conditions, we developed a spreadsheet computer program for roof beam analysis. The computer program used does not distinguish between individual and composite beam theories, it calculates both. In reviewing the computer generated results in Appendix B, the lowest of the two safety factors listed will represent the applicable theory.

In this analysis failure of all beams must occur before subsidence is expressed on the surface.

A determination of the minimum beam thickness required to span across rooms was made using a calculated safety factor of 1.5 as the limiting value. The value of 1.5 was selected as it allows a reasonable variation in material properties, and we believe those assigned to be slightly conservative. The following table presents the minimum lower beam thickness to provide a calculated safety factor greater than 1.5 for each of the cases illustrated in Figure 4.

Seam No.	Beam Thickness, ft.	Safety Factor
1 1/2	1	1.7
2	1	1.9
4	0.5	1.7
5	1.5*	2.0

* Note: The lower beam, 15 feet thick, was shown to fail. This thickness is in the second beam above the mined seam.

This table shows that massive roof collapse is not likely if bedding planes or discontinunities are farther apart than the minimum beam thickness. Our observations of the core indicates bedding planes and discontinunities are generally greater than 1 to 1.5 feet apart. As a result we would not predict massive roof collapse to be a common failure mode. The only analyzed location where the calculation predicted roof collapse was within the first 15 feet above the No. 5 Seam. That prediction appears to be reasonably consistent with conditions encountered in the borings.

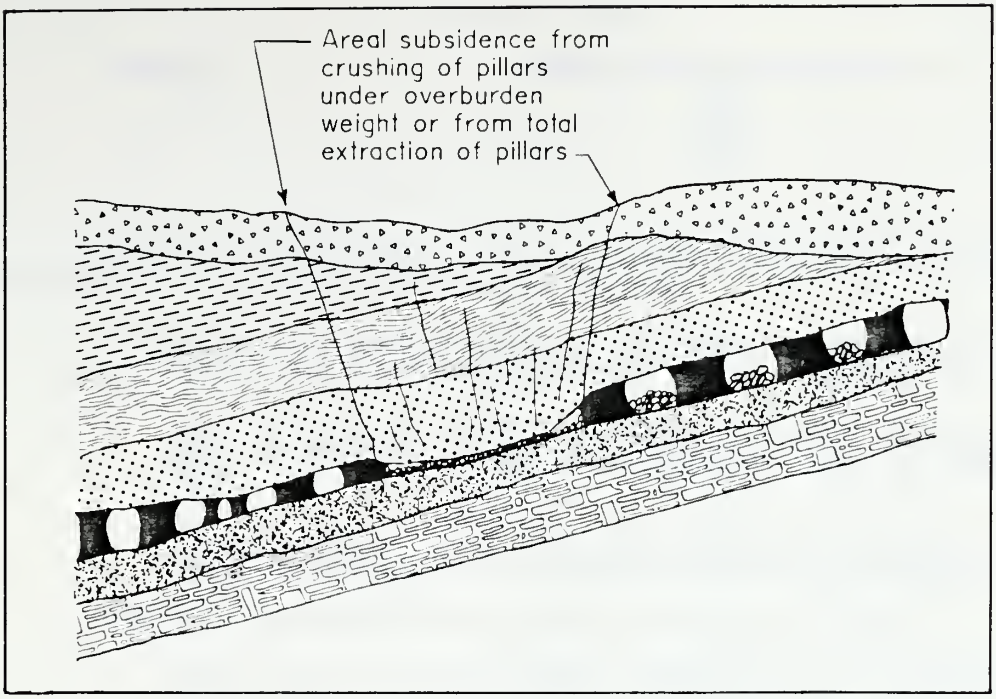
C. Pillar Crushing

Pillars crush when the overburden pressure exceeds the strength of the pillars. Once a pillar fails the overburden load it carried is either transferred to adjacent pillars, which may in turn fail, or the roof collapse mode of failure might occur. Figure 5 illustrates the concept of tributary areas for calculating loads supported by pillars.

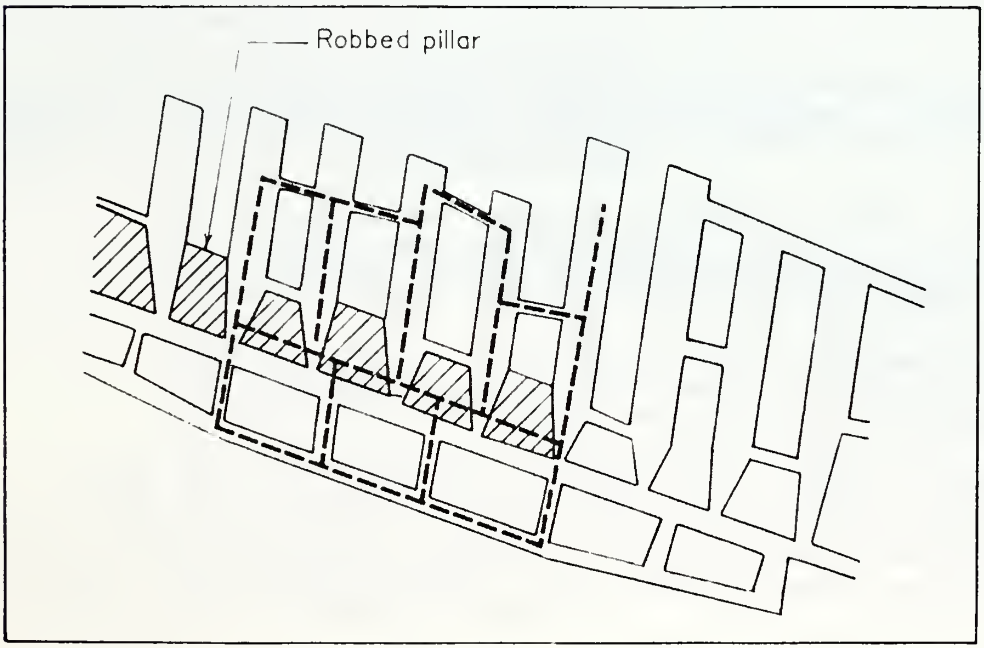
As noted earlier, the coal strength has been estimated using cubes cut from samples originating from the Smith No. 2 Seam. Sample calculations and computer generated results for this mode are presented in Appendix B. The analysis included correction factors for the size of cubes and pillar height to width ratios. The calculation is most sensitive to overburden pressure and strength of the coal. As stated previously we believe the critical load condition occurred during mining when rooms were dewatered. The flooded condition generally reduces the overburden pressure and thus increases the safety factor by a factor of about 1.7.

The condition of dipping beds creates changing overburden pressures along the length of rooms. For simplicity we used the average overburden pressure throughout each area analyzed. It is not known how the dipping beds influence the state of stress within pillars. It can be argued that a portion of the overburden load is transmitted through pillars in shear rather than purely compression. Considering that the long dimension of pillars is generally in the direction of dip and the length to height ratio is usually greater than 5 to 10, we believe the influence of these dip angles is negligible.

The rock profiles analyzed were typical of DH-1 and 3. Room and pillar configurations were selected which appeared representative. The calculations generally yield safety factors in the range of 2 to 3 for the submerged condition. Predictably safety factors will decrease down dip, and in deeper seams. For the dewatered condition which existed during mining, pillar failures are often predicted. It is possible the laboratory tests under estimate the coal strength in those seams, or stress redistributions (temporary arching) influenced performance during mining. Observation of the mine maps do not normally show pillar sizes increasing at greater depths. The following table presents the approximate depths below which we would predict pillar crushing to occur for the submerged condition.



5a. Cross Section of Loaded Pillars



5b. Plan View of Typical Pillar Configurations

Figure 5 Pillar Crushing Failure Mode

Seam No.	Approximate Crushing Depth, ft.
1-1/2	700
2	700
4	350
5	800

Comparing these depth estimates with the cross sections on Drawing No. 87-3001.D-7, the following observations are made:

- On the east bench cross section all mines extend significantly deeper than our calculations would predict possible.

- On the Main Street cross section, the mines generally stop near the depths we predict can be supported for the submerged case.

- On the airport cross section, the No. 1-1.2 and No. 4 seams extend below the depths our calculations predict possible.

From these observations the following conclusions are made:

1. Either the coal has greater strength than predicted by laboratory tests, or pillars in these deeper sections have been crushed.

2. Since the mines have been inactive for at least 50 years and flooding has reduced overburden pressures to buoyant conditions, future pillar crushing is unlikely.

D. Pillar Punching

Analysis methods for pillar punching have been developed (8 and 9) which are considered reasonably accurate. Based upon conditions of materials encountered in the borings however, we do not consider a calculation for pillar punching necessary for the following reasons.

- The thickness of soft underclay encountered in the core was thin, typically about one foot or less.
- Floor materials beneath the underclay are very competent such that pillars would obviously crush before the floor would yield.
- The consistency of the underclay is so soft that it was so badly disturbed by coring that samples for strength tests could not be obtained. It is the weakest material encountered.

From these observations we conclude that pillars have probably already punched some distance, but the underlying competent materials prevented punching of more than a few feet. We perceive this limited depth of punching as being the potential catalyst to initiating the limited roof strain and collapse. As pillars move down roof support decreases, and in effect increases the distance roof beams must span.

E. Trough Subsidence Geometries

These calculations were performed utilizing methods presented and referenced by Peng (6). The technique was developed for use in British longwall mines and is generally considered to over estimate subsidence in U.S. mines, especially room and pillar mines. It does allow some modification to trough geometry due to dipping beds. This is purely a graphical method which ignores material strength properties except for their influence on the angle of draw.

Figures 6, 7, 8 and 9 present typical trough geometries for the following cases.

- No. 1 1/2 Seam for subsidence of a single room.
- No. 4 Seam for subsidence of two adjacent rooms if pillar is robbed.
- No. 4 Seam for subsidence of numerous adjoining rooms to simulate mass pillar robbing.
- No. 4 and 5 Seams for subsidence of two overlying areas of mass pillar robbing.

The last case of two overlying areas is not presented in the literature. Our analysis was to predict the trough geometry for subsidence of each area and then use superposition to construct the final geometry.

Figures 6 through 9 suggest that surface subsidence from a single room might only be in the range of a few inches, while multiple room and multiple seam subsidence is predicted to result in much greater surface subsidence. These figures are presented only for informational purposes. We are not aware of any previous subsidence features which can be represented by these constructions. Furthermore the condition of mine roofs and rooms observed in the borings present no indication which would lead us to believe the figures represent potential future surface subsidence. All indications suggest that bulking is preventing mine room failures from being expressed on the surface, except where chimneys have developed in high potential areas.

V. SUMMARY AND CLOSING

Through the process of reviewing mine maps, strategic location of exploration borings, observing subsidence features and performing calculations using representative material properties we believe the following summary statements can be made.

1. Evidence of rock strain is generally limited to less than 20 feet above predicted mine roofs.
2. The perceived failure mode consists of a limited distance of pillar punching followed by some roof collapse which has probably stabilized.
3. Because most of the mines are now flooded, present day conditions are generally less conducive to subsidence than existed during or shortly after the mines were operating.

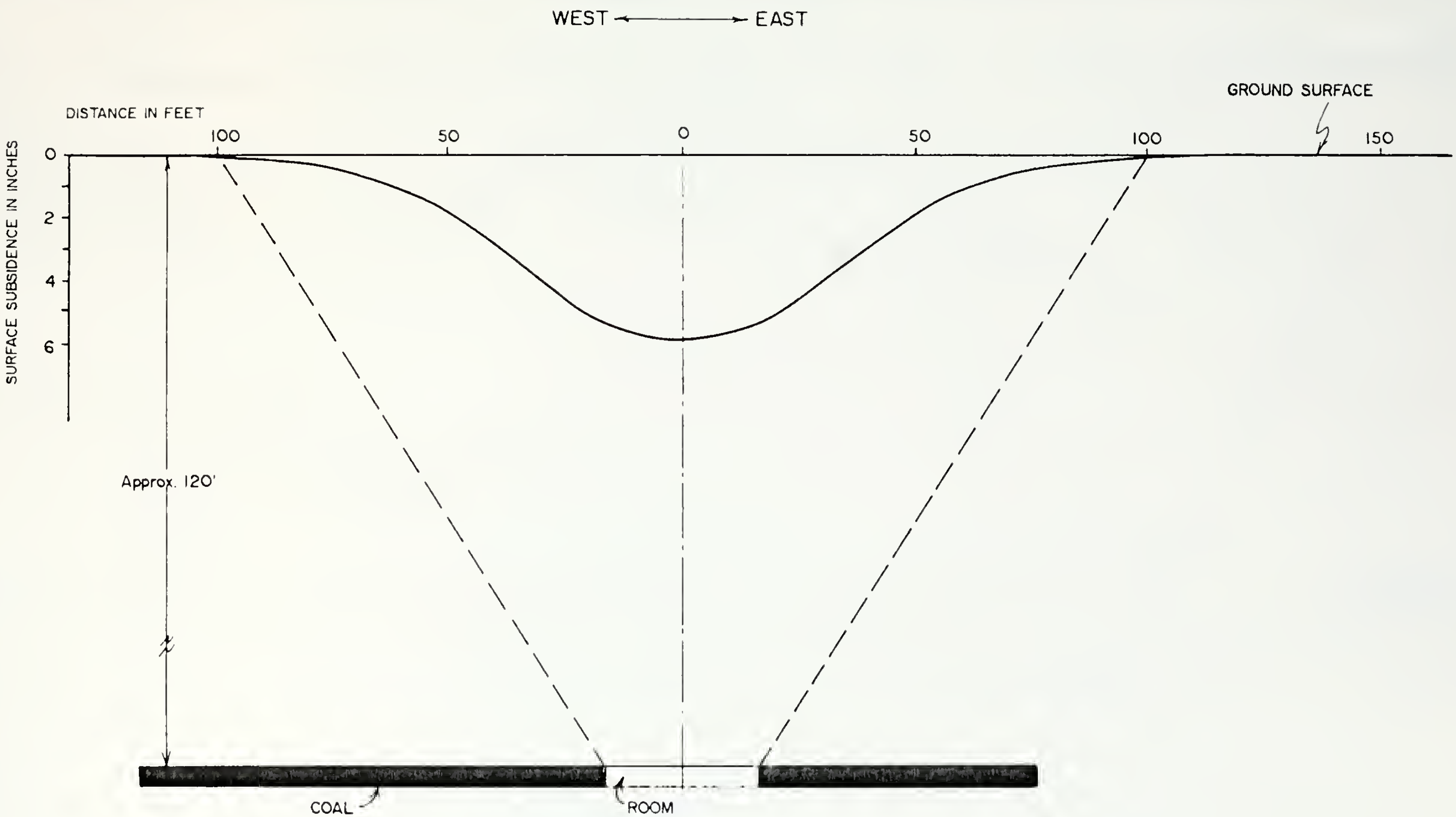


Figure 6 East-West Trough Geometry for Single Room in No. 1-1/2 Seam

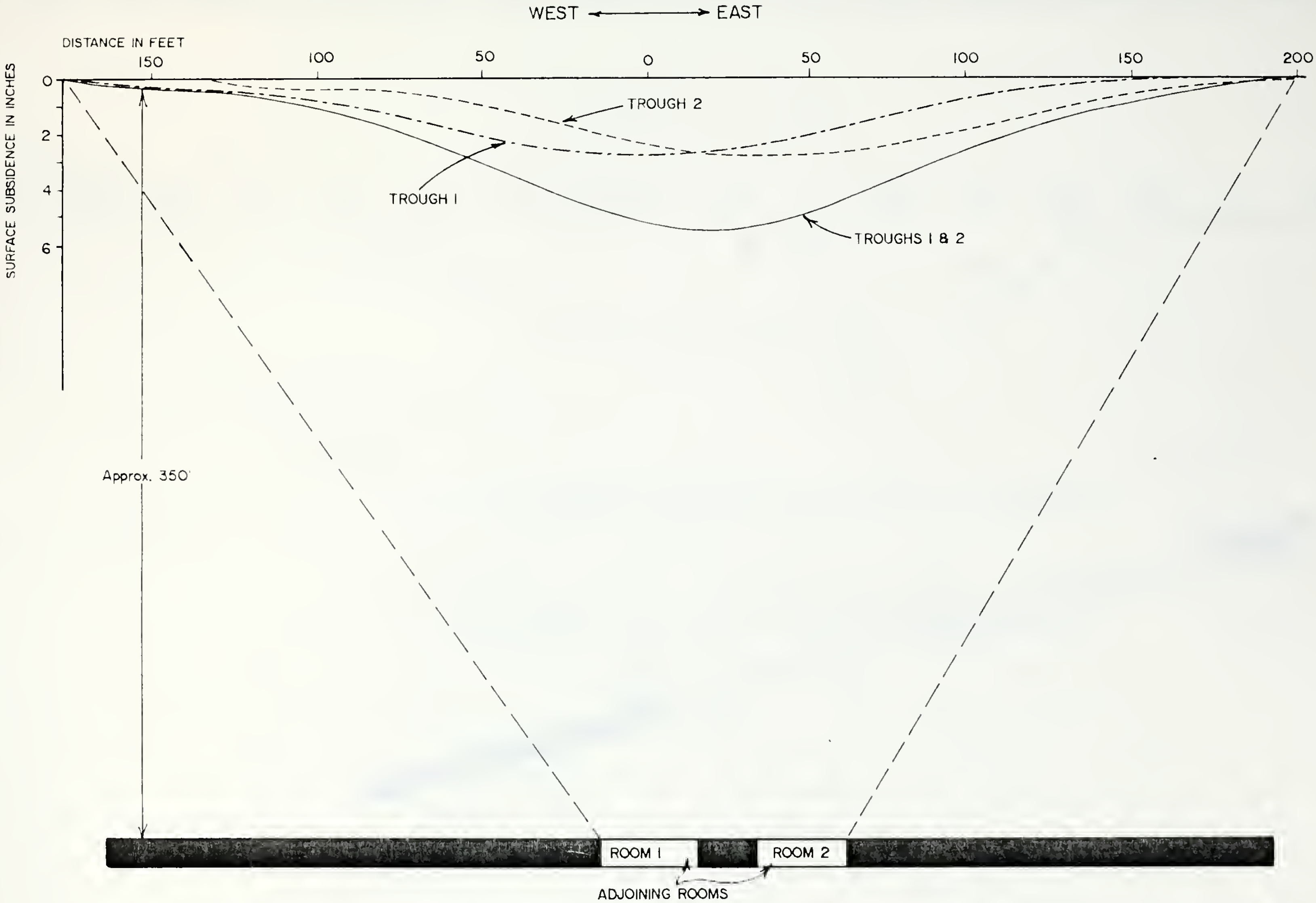


Figure 7 East-West Trough Geometry for 2 Adjoining Rooms in No. 4 Seam

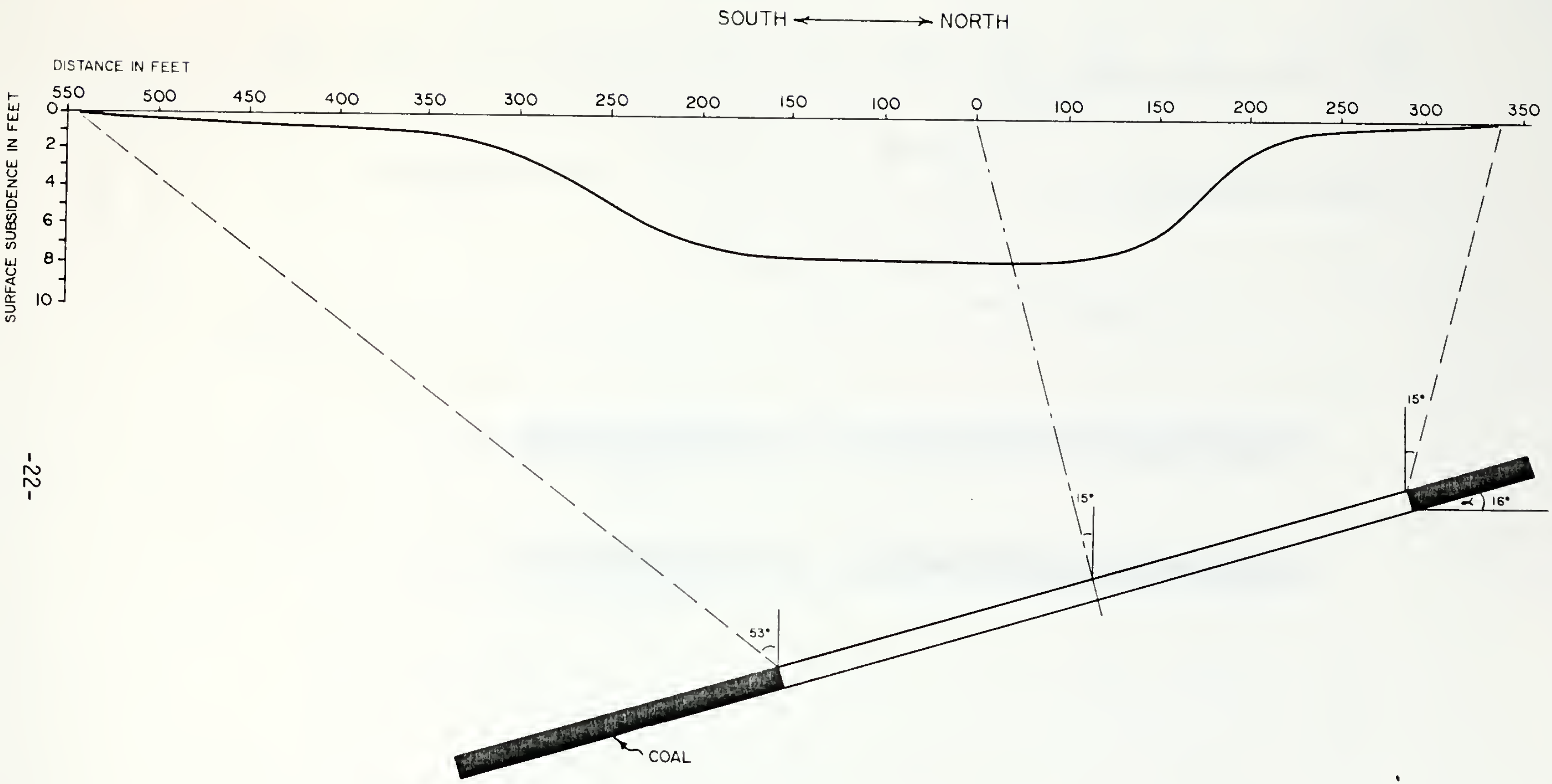


Figure 8 North-South Trough Geometry for Multiple Room Extractions in No. 4 Seam

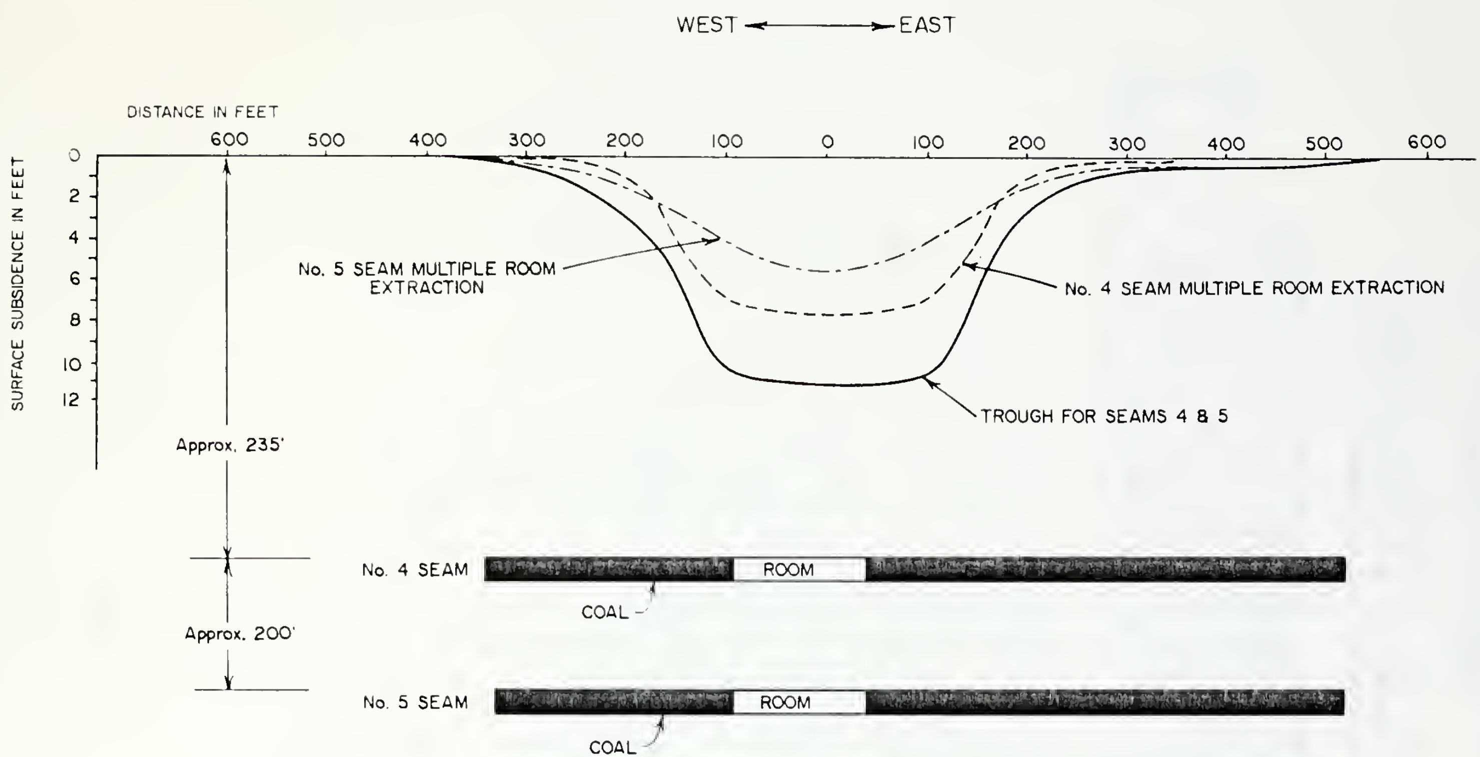


Figure 9 East-Weast Trough Geometry for Multiple Room Extractions in Seams 4 & 5

4. The potential for future subsidence is considered high only on the Bill Palmer property east of Red Lodge, near the west end of 10th Street, and above shallow adits in the Bearcreek area. It is predicted to consist of chimney subsidences similar to previous occurrences.

5. Two small areas within the town and part of the runway classify as having a moderate potential. The Red Lodge Subsidence Potential map is presented on page 12.

In making the above statements we concede the fact that the mines cover an extensive area and our subsurface explorations are very limited in relation to the mined area. It is therefore possible that conditions different than those encountered exist and might produce future subsidence. However, in view of the information contained in this report and the historical development of subsidence in other western coal fields we believe the potential for future surface expression of mine subsidence beneath presently developed areas is generally low.

BIBLIOGRAPHY

1. Bieniawski; Rock Mechanics Design in Mining and Tunneling, A.A. Balkema, Boston, 1984

2. Brown; Methods of Locating Potential Subsidence Areas, Proceedings of The Governor's Workshop on Mine Subsidence, Laramie, WY, 1986

3. Karfakis; Mechanisms of Subsidence over Abandoned Coal Mines, Proceedings of The Governor's Workshop on Mine Subsidence, Laramie, WY, 1986

4. Kiewit Mining Company; Reclamation Recommendations Red Lodge Coal Field; Sheridan, WY, 1983

5. National Coal Board; Subsidence Engineers Handbook, London, 1975

6. Peng; Coal Mine Ground Control, Second Edition, John Wiley & Sons, New York, 1986

7. Piggot & Eynon; Ground Movements Arising from the Presence of Shallow Abandoned Mine Workings, in Geddes, ed. Large Ground Movements and Structures, Halstead Press, New York, 1977

8. Rockaway & Stephenson; Geotechnical Evaluation of the Support of Coal Pillars in Underground & Coal Mines, Bulletin of the Association of Engineering Geologists, Vol. XIX, No. 1, 1982

9. Vesic; Bearing Capacity of Shallow Foundations, in Winterkorn and Fang, Foundation Engineering Handbook, Van Nostrand Reinhold Co., New York, 1973

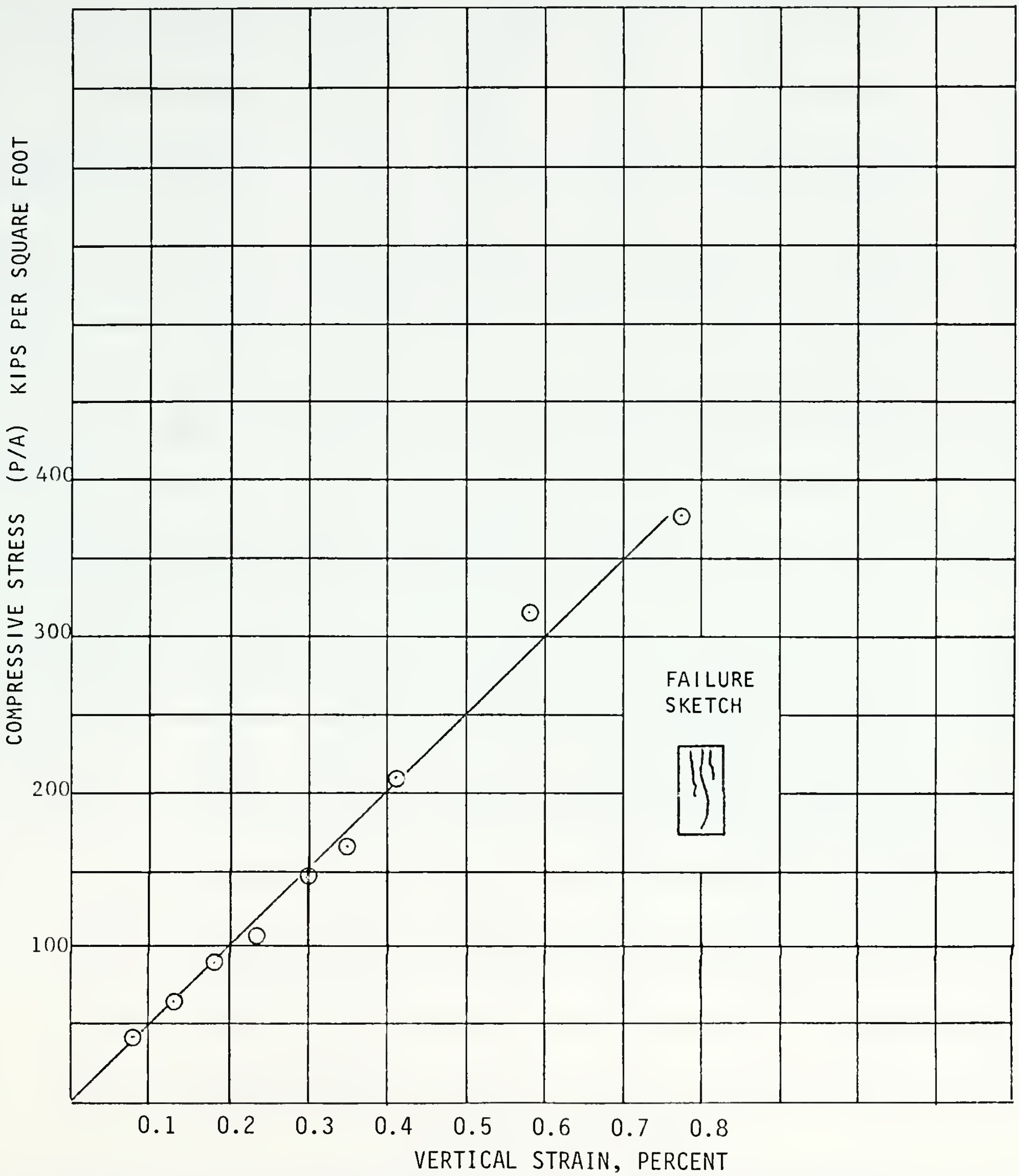
10. Wright; Roof Control Through Beam Action and Arching, in Given (editor), SME Mining Engineering Handbook, American Institute of Mining, Metallurgical and Petroleum Engineers, New York, 1973

APPENDIX A

UNCONFINED COMPRESSION TEST

DRILL HOLE DH-1
DEPTH 135.0'-136.0'
SAMPLE NO.

MOIST UNIT WEIGHT: 153 pcf.
DRY UNIT WEIGHT : 146 pcf.
MOISTURE CONTENT : 4 %
CLASSIFICATION : Sandstone
HEIGHT TO DIAMETER RATIO: 2.06
RATE OF STRAIN: 0.08%/min.



RED LODGE/BEARCREEK SUBSIDENCE STUDY
RED LODGE, MONTANA

STATE OF MONTANA DEPARTMENT OF STATE LANDS
ABANDONED MINE RECLAMATION BUREAU
HELENA, MONTANA

Northern Engineering and Testing, Inc.

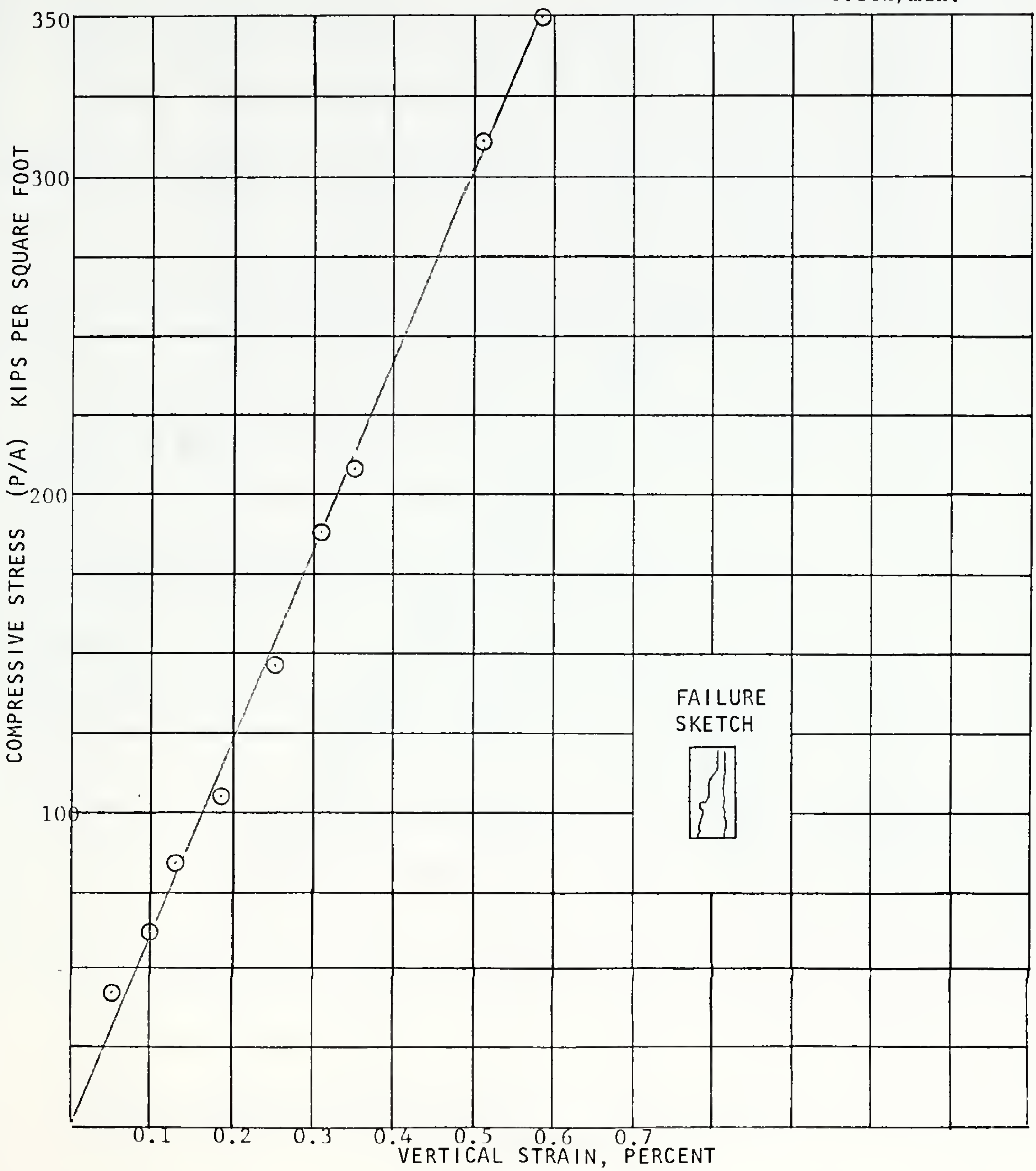
JOB NO. 87-3001.D PLATE NO. 1

NET 158

UNCONFINED COMPRESSION TEST

DRILL HOLE DH-1
DEPTH 136.0'-137.0'
SAMPLE NO.

MOIST UNIT WEIGHT: 153 pcf.
DRY UNIT WEIGHT : 147 pcf.
MOISTURE CONTENT : 4 %
CLASSIFICATION : Sandstone
HEIGHT TO DIAMETER RATIO: 2.05
RATE OF STRAIN: 0.10%/min.



RED LODGE/BEARCREEK SUBSIDENCE STUDY
RED LODGE, MONTANA

STATE OF MONTANA DEPARTMENT OF STATE LANDS
ABANDONED MINE RECLAMATION BUREAU
HELENA, MONTANA

Northern Engineering and Testing, Inc.

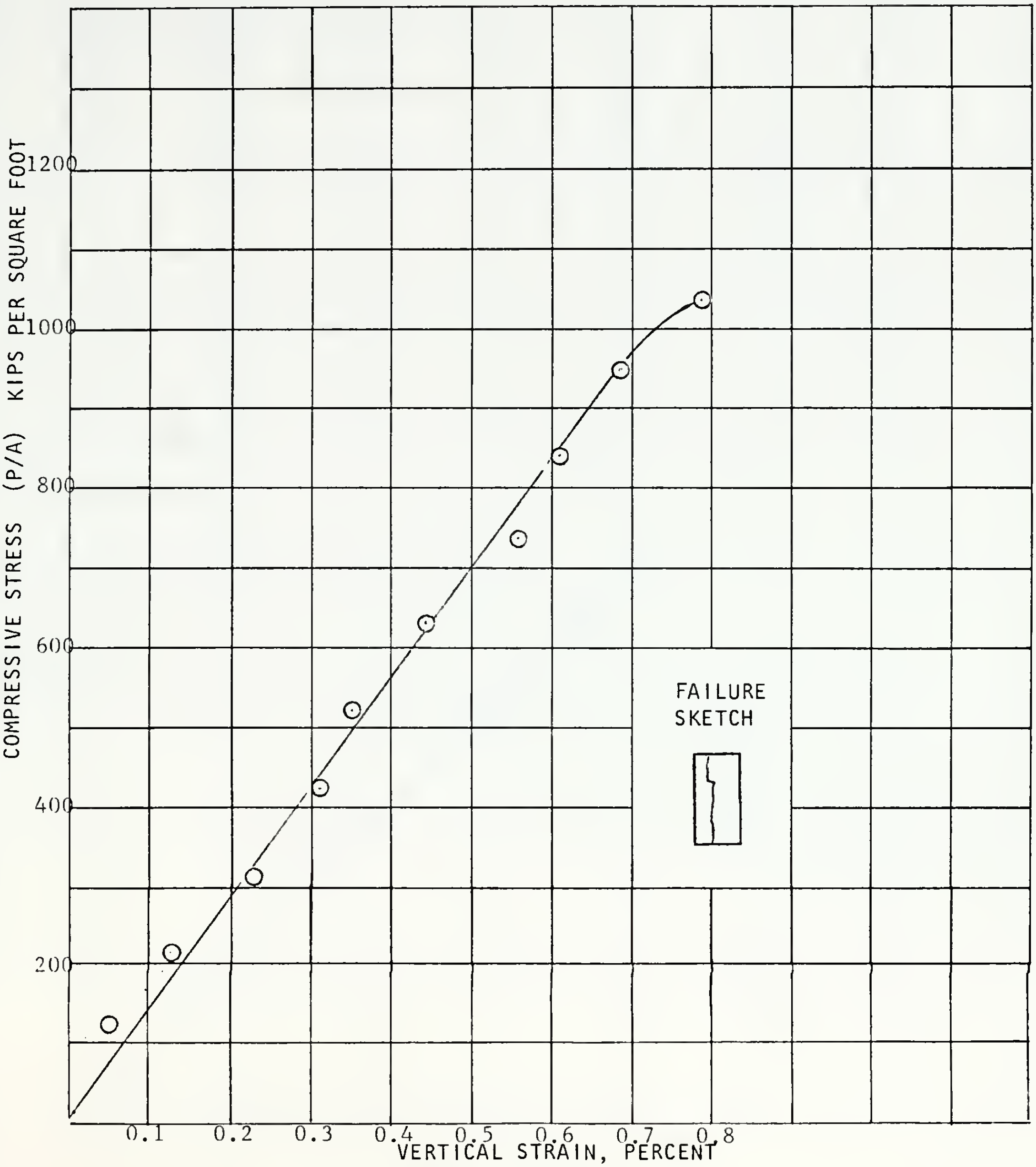
JOB NO. 87-3001.D PLATE NO. 2

NET 158

UNCONFINED COMPRESSION TEST

DRILL HOLE DH-3
DEPTH 212.0'-213.0'
SAMPLE NO.

MOIST UNIT WEIGHT: 155 pcf.
DRY UNIT WEIGHT : 152 pcf.
MOISTURE CONTENT : 2 %
CLASSIFICATION : Claystone
HEIGHT TO DIAMETER RATIO: 2.05
RATE OF STRAIN: 0.09%/min.



RED LODGE/BEARCREEK SUBSIDENCE STUDY
RED LODGE, MONTANA

STATE OF MONTANA DEPARTMENT OF STATE LANDS
ABANDONED MINE RECLAMATION BUREAU
HELENA, MONTANA

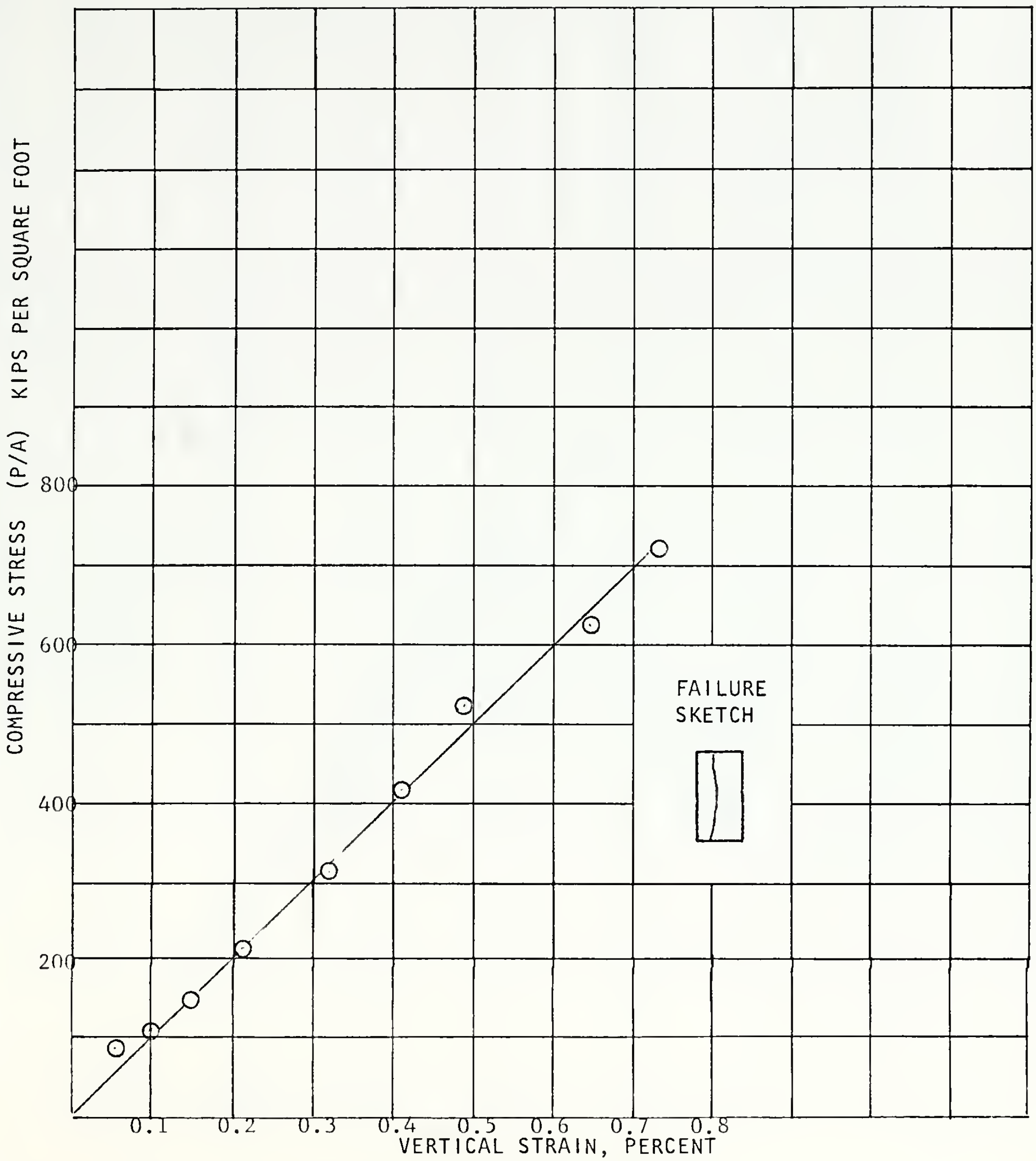
Northern
Engineering
and Testing, Inc.

JOB NO. 87-3001.D PLATE NO. 3

UNCONFINED COMPRESSION TEST

DRILL HOLE DH-4
DEPTH 225.4'-226.3'
SAMPLE NO.

MOIST UNIT WEIGHT: 155 pcf.
DRY UNIT WEIGHT : 151 pcf.
MOISTURE CONTENT : 2 %
CLASSIFICATION : Claystone
HEIGHT TO DIAMETER RATIO: 2.09
RATE OF STRAIN: 0.06%/min.

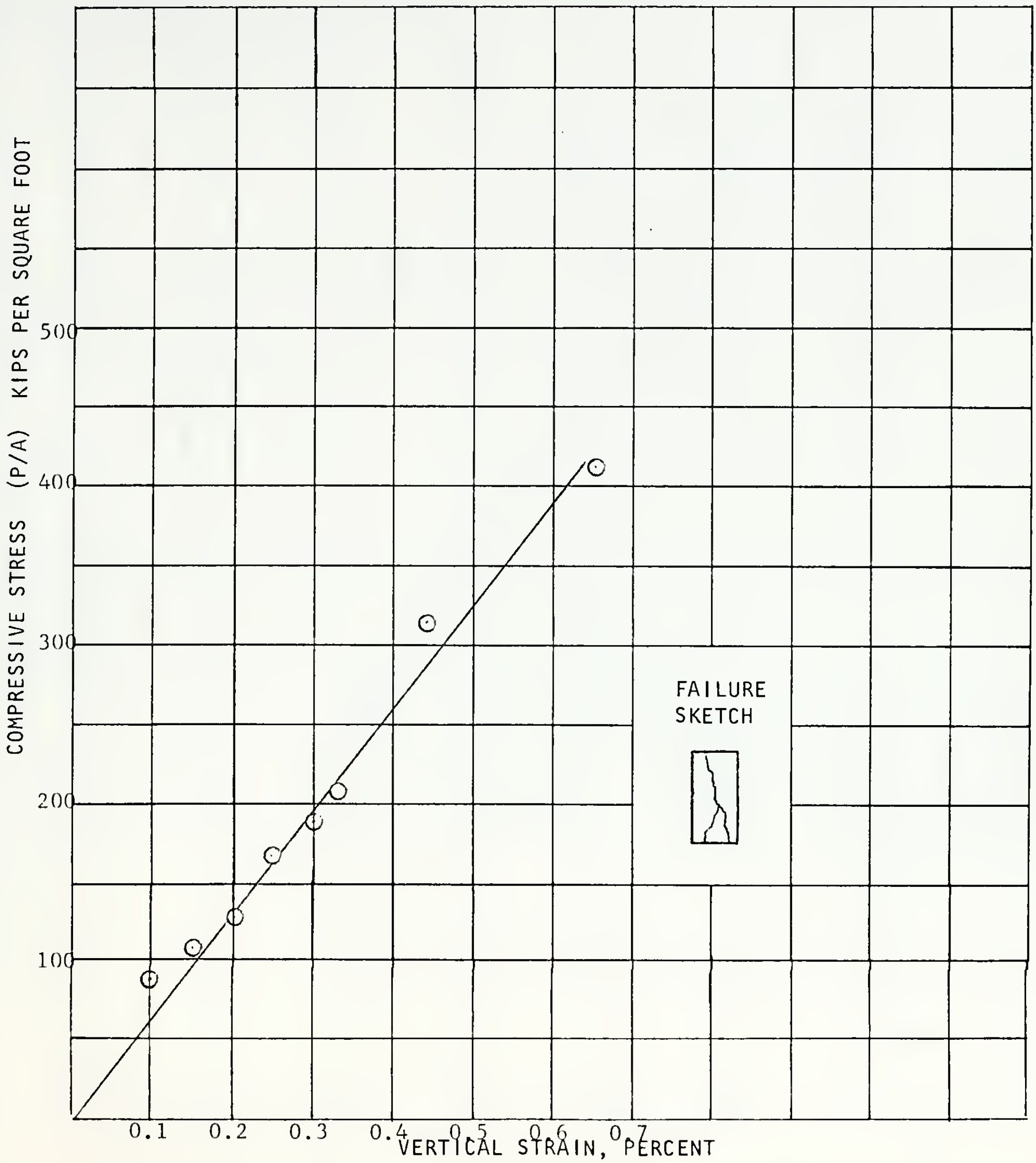


RED LODGE/BEARCREEK SUBSIDENCE STUDY RED LODGE, MONTANA	Northern Engineering and Testing, Inc.
STATE OF MONTANA DEPARTMENT OF STATE LANDS ABANDONED MINE RECLAMATION BUREAU HELENA, MONTANA	JOB NO. 87-3001.D PLATE NO. 4

UNCONFINED COMPRESSION TEST

DRILL HOLE DH-3
DEPTH 414.0'-414.7'
SAMPLE NO.

MOIST UNIT WEIGHT: 145 pcf.
DRY UNIT WEIGHT : 138 pcf.
MOISTURE CONTENT : 5 %
CLASSIFICATION : Sandstone
HEIGHT TO DIAMETER RATIO: 2.06
RATE OF STRAIN: 0.09%/min.



RED LODGE/BEARCREEK SUBSIDENCE STUDY
RED LODGE, MONTANA

STATE OF MONTANA DEPARTMENT OF STATE LANDS
ABANDONED MINE RECLAMATION BUREAU
HELENA, MONTANA

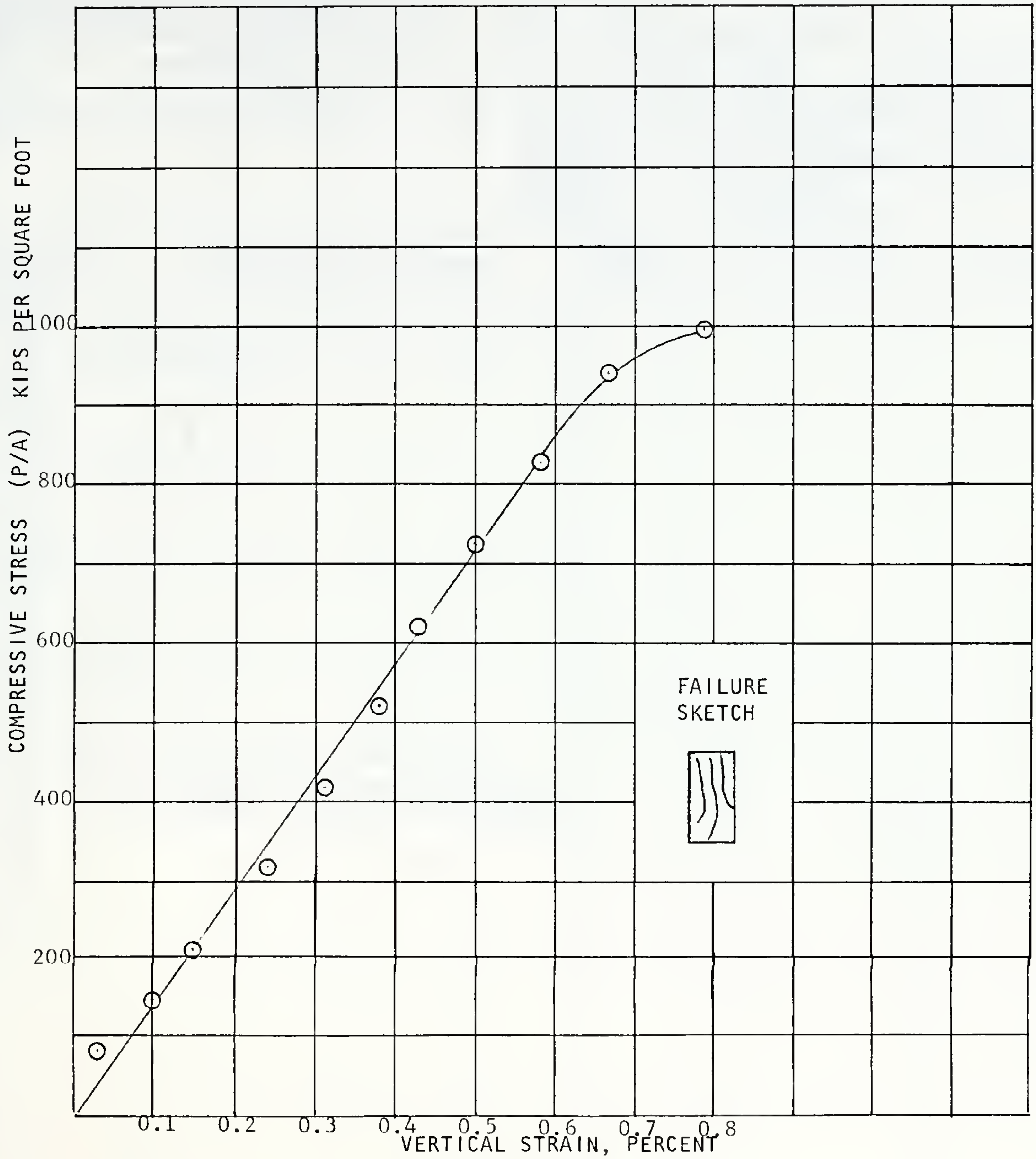
Northern Engineering and Testing, Inc.

JOB NO. 87-3001.D PLATE NO. 5

UNCONFINED COMPRESSION TEST

DRILL HOLE DH-3
DEPTH 441.2'-442.0'
SAMPLE NO.

MOIST UNIT WEIGHT: 154 pcf.
DRY UNIT WEIGHT : 151 pcf.
MOISTURE CONTENT : 2 %
CLASSIFICATION : Sandstone
HEIGHT TO DIAMETER RATIO: 1.97
RATE OF STRAIN: 0.13%/min.



RED LODGE/BEARCREEK SUBSIDENCE STUDY
RED LODGE, MONTANA

STATE OF MONTANA DEPARTMENT OF STATE LANDS
ABANDONED MINE RECLAMATION BUREAU
HELENA, MONTANA

Northern Engineering and Testing, Inc.

JOB NO. 98-3001.D PLATE NO. 6

NET 158

Northern
Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH-1
SHEET 1 OF 3

DRILL TYPE: SOIL ROCK Schramm Rotadrill	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 3" Core 7-7/8 & 6-1/4 Tricone	PROJECT Red Lodge/Bearcreed Subsidence Study
CASING: SIZE 8-5/8" LENGTH 108'	LOCATION Red Lodge Airport
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN Disturbed / Undisturbed	ELEVATION: TOP OF HOLE Not Determined GROUNDWATER 118'
TOTAL NO. CORE BOXES 5 TOTAL CORE RECOVERY FOR BORING (%) 77	THICKNESS OF OVERBURDEN, FT. 91.0 DEPTH DRILLED INTO ROCK, FT. 134 TOTAL DEPTH OF HOLE, FT. 225
REMARKS	STARTED 7-20-87 COMPLETED 7-23-87
	DRILLED BY B. Kupfner
	LOGGED BY R. Dombrouski

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
0–7.0		FILL; Mine Spoils				
7.0–80 (20, 40, 60)		Poorly Graded GRAVEL with Cobbles and Boulders; very dense, rounded to subrounded, difficult penetration.				
80		(continued ....)				

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-1 SHEET 2 OF 3

DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	GEOMECHANICAL: DEGREE OF WEATHERING	JOINTS/FT	DISCONTINUITIES: TYPE	DIP
80	Poorly Graded GRAVEL with Cobbles and Boulders.							
91	Lean CLAY; very stiff, brown, decomposed claystone.							
101	SANDSTONE; gray, very fine grained, moderately hard to hard rock.							
108	CLAYSTONE; light to dark gray, soft to moderately hard rock, interbedded with thin sandstone seams.							
118	GWL (7-23-87)							
	Becoming broken with thin coal and carbonaceous seams below 117 feet.	50	21	120-134	SW	I	BJ/OX	17°
					SW	I	OJ/OX	85°
129	COAL No. 1-1/2 Seam, highly fractured.				SW	I	BJ	80°
134	SANDSTONE; gray, very fine grained, moderately hard to hard rock.	96	87	134-154	SW	I	CJ	20°
146.7	CLAYSTONE; dark gray.							
150	SANDSTONE; light gray, very fine grained, argillaceous, moderately hard rock.							
160								
180								
190	(continued ....)							

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-1 SHEET 3 OF 3

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	BLOWS/FOOT
190		SANDSTONE; light gray, very fine grained, argillaceous, moderately hard rock.				
200		VOID				
205		Broken Rock Rubble				
216		CLAYSTONE; Mine Floor				
225		Bottom of Hole				


DH 1


DH-1
122.0 -124.0


DH 1
124.0 - 125.0


DH 1
125.0 - 134.0
126.0


DH 1
134.0 - 136.0


DH 1
136.0 - 138.0


DH 1
138.0-140.0


DH 1
140.0-142.0


DH 1
142.0 - 144.0


DH 1
144.0 - 146.0


DH 1
146.0 - 148.0


DH 1
148.0 - 150.0


DH 1
150.0 - 152.0


DH 1
152.0 - 154.0

Northern Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH - 2
SHEET 1 OF 4

DRILL TYPE: SOIL / ROCK Bucyrus Erie	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 3" Core, 7-7/8 Tricone	PROJECT Red Lodge/Bearcreek
CASING: SIZE 8-5/8 LENGTH 75'	LOCATION East Bench 8' North of section corner 7,26,4,35
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: Disturbed / Undisturbed	ELEVATION: TOP OF HOLE Approximately 5835; GROUNDWATER 27.3
TOTAL NO. CORE BOXES 8; TOTAL CORE RECOVERY FOR BORING (%) 97	THICKNESS OF OVERBURDEN, FT. 21.0; DEPTH DRILLED INTO ROCK, FT. 349; TOTAL DEPTH OF HOLE, FT. 370'
REMARKS	STARTED 8-10-87; COMPLETED 8-19-87
	DRILLED BY Rock Creek Drilling (B. Kupfner)
	LOGGED BY R. Dombrouski

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
0.4		TOPSOIL				
		Lean CLAY; firm, moist to wet, occasional sand seams.				
21						
27.3		GWL (8-19-87)				
40						
		CLAYSTONE; light gray to light brown, soft rock, thinly laminated, carbonaceous seams.				
60						
80		(continued ......)				

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-2 SHEET 2 OF 4

DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	BLOWS/FOOT
80	CLAYSTONE				
87	SANDSTONE; Gray, very fine grained, soft rock, argillaceous.				
97	CLAYSTONE; Dark gray, thinly bedded, soft rock.				
120					
135	SANDSTONE; Gray, very fine grained, soft rock, argillaceous.				
144	CLAYSTONE; Dark gray, thinly bedded, soft rock, thin carbonaceous layers.				
155	SANDSTONE; Light gray, soft rock.				
159	CLAYSTONE; Dark gray, soft to moderately hard rock,thinly laminated occassional coal and carbonaceous seams				
180					

(continued ......)

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-2 SHEET 3 OF 4

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	BLOWS/FOOT
190						
200						
220						
		CLAYSTONE; Dark gray, soft to moderately hard rock, thinly laminated, occassional coal and carbonaceous seams.				
240						
260						
280						
300		(continued ....)				

NET 122E

LOG OF EXPLORATION BORING

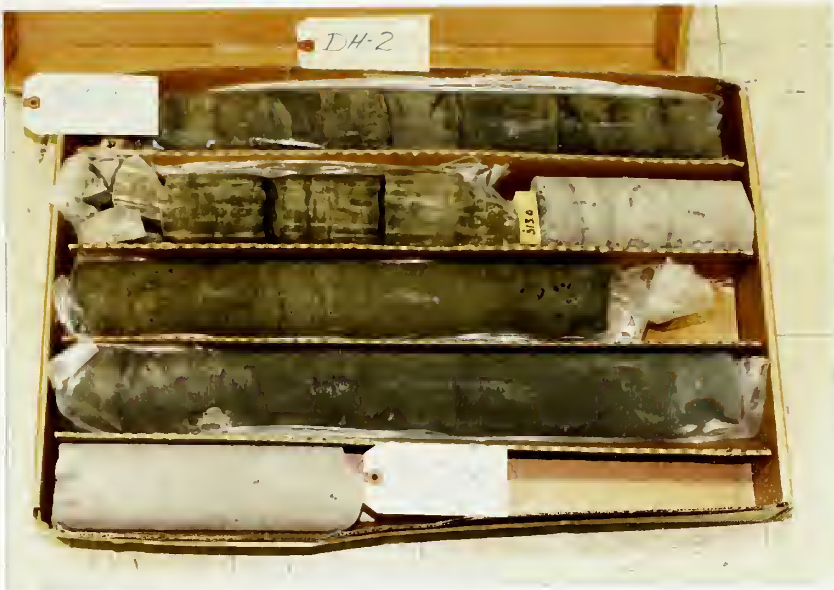
JOB NO. 87-3001.D HOLE NO. DH-2 SHEET 4 OF 4

DEPTH, FT.	CLASSIFICATION OF MATERIALS
300	CLAYSTONE; Dark gray, soft to moderately hard rock, thinly laminated, occassional coal and carbonaceous seams.
310	SANDSTONE; Light gray, very fine grained, moderately hard rock, argillaceous seams, some carbon detrius and thin coal layers.
320	
328.7	CLAYSTONE; Dark gray, carbonaceous, sandy, moderately hard rock, thin sandstone seams, some fractured zones.
349	SANDSTONE; Light gray, very fine grained, hard rock.
355	CLAYSTONE; Gray, sandy, moderately hard rock
358	COAL; Highly fractured.
358.5	CLAYSTONE; Gray, soft at contact then hard.
370	Bottom of Hole

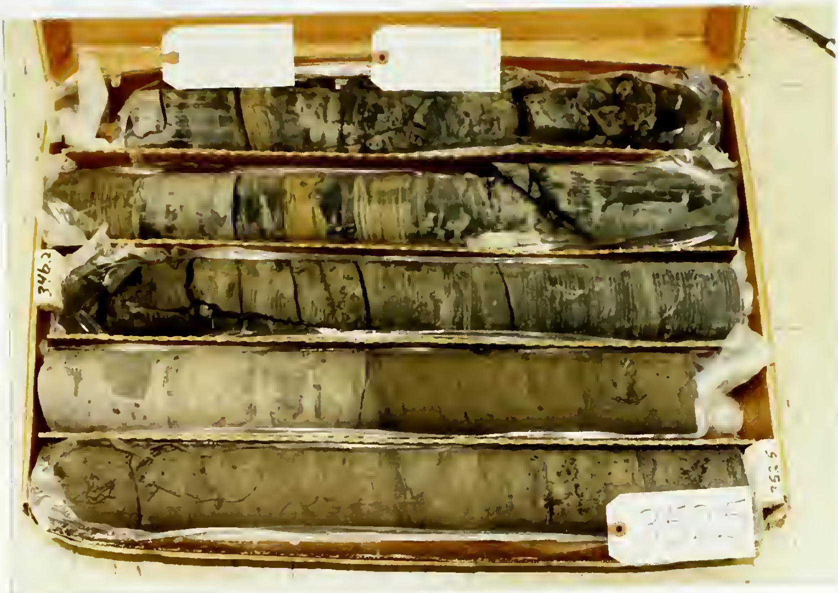
% CORE RECOVERY	RQD	DEPTH, FEET
100	100	310-313
100	96	313-333
100	89	333-346.2
89	81	346.2-360

GEOMECHANICAL

DEGREE OF WEATHERING	JOINTS/FT	DISCONTINUITIES TYPE	DISCONTINUITIES DIP
SW	2	CJ	11°
SW		OJ	8°
F	2	BJ	
SW	2	OJ	46°/88°
SW	1	OJ	64°
MW	2	OJ Gauge	53°
MW	2	OJ	76°
SW	1	OJ	65°
SW	2	OJ	60°
SW	1	OJ	89°
MW	1	CJ	—


DH-2


DH-2


352.5


352.5

Northern Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH-3

SHEET 1 OF 5

DRILL TYPE: SOIL ROCK Schramm Rotadrill	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 7-7/8", 6-1/4" & 3" Core Tricones 10-5/8"	PROJECT Red Lodge/Bearcreek
CASING: SIZE 8-6/8" LENGTH 110'	LOCATION On 14th Street, 170' West of Main Street, 10' South of North Curb
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN Disturbed / Undisturbed	ELEVATION: TOP OF HOLE Not Determined; GROUNDWATER 27
TOTAL NO. CORE BOXES 9 / TOTAL CORE RECOVERY FOR BORING (%) 76	THICKNESS OF OVERBURDEN, FT. 108' / DEPTH DRILLED INTO ROCK, FT. 342.5 / TOTAL DEPTH OF HOLE, FT. 450.5
REMARKS	STARTED 7-23-87 / COMPLETED 7-31-87
	DRILLED BY Rock Creek Drilling
	LOGGED BY R. Dombrouski

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
1.0		FILL; Silty Sand				
20						
27		GWL (7-31-87)				
40		Poorly Graded GRAVEL with cobbles and boulders; very dense, rounded to subrounded, difficult penetration.				
60						
80		(continued.....)				

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D **HOLE NO.** DH-3 **SHEET** 2 **OF** 5

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R Q D	DEPTH, FEET	BLOWS/FOOT
80		Poorly Graded GRAVEL with cobbles and boulders; very dense, rounded to subrounded, difficult penetration.				
100						
108		SANDSTONE; Gray, very fine grained, moderately well cemented, argillaceous.				
120						
140						
160						
180						

(continued.......)

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-3 SHEET 3 OF 5

DEPTH FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	GEOMECHANICAL: DEGREE OF WEATHERING	JOINTS/FT	DISCONTINUITIES: TYPE	DISCONTINUITIES: DIP
190–205		SANDSTONE; Gray, very fine grained, moderately well cemented, argillaceous.							
205–227.8		CLAYSTONE; dark gray, sandy, moderately hard rock, laminated, becoming light gray and more sandy below 212 feet with some carbon detritus.	95	89	210-230	F	O	Bd	17°
						all breaks drilling induced			
						Broken Rock			
227.8–237		COAL; Highly fractured	69	0	230-241				
237–245		CLAYSTONE; Dark gray, carbonaceous, soft at contact, thinly laminated.							
245–300		SANDSTONE; Light gray, very fine grained, argillaceous.							

(continued ....)

NET 122E

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-3 SHEET 4 OF 5

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R Q D	DEPTH, FEET	BLOWS/FOOT
300						
320						
340		SANDSTONE; Light gray, very fine grained, argillaceous.				
360						
380						
400						
		(continued ......)				

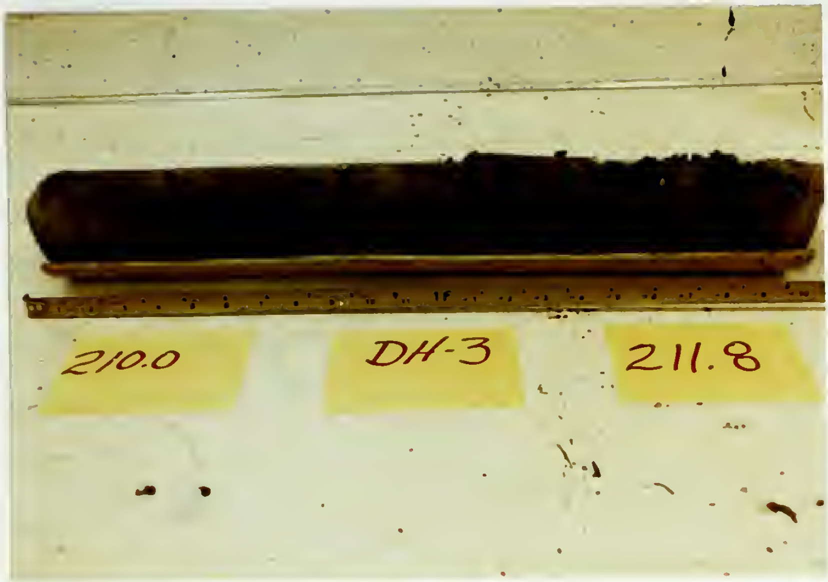
LOG OF EXPLORATION BORING

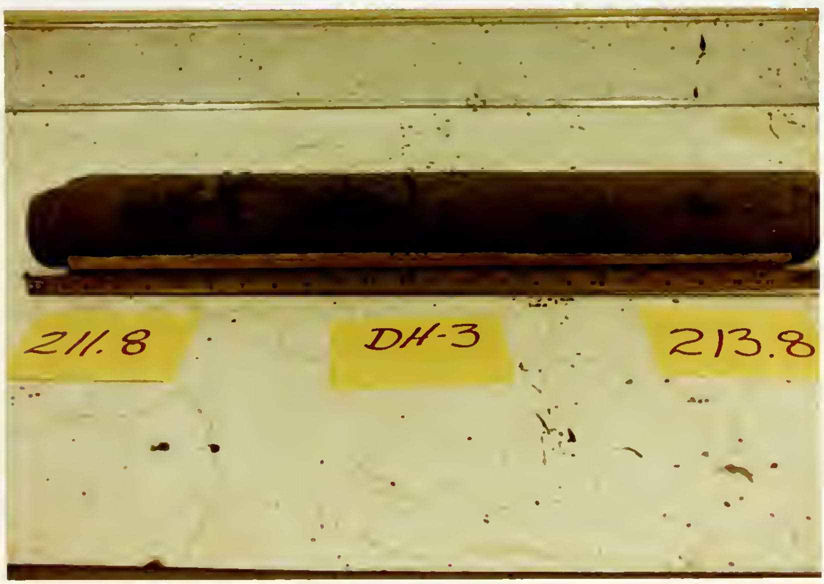
JOB NO. 87-3001.D HOLE NO. DH-3 SHEET 5 OF 5

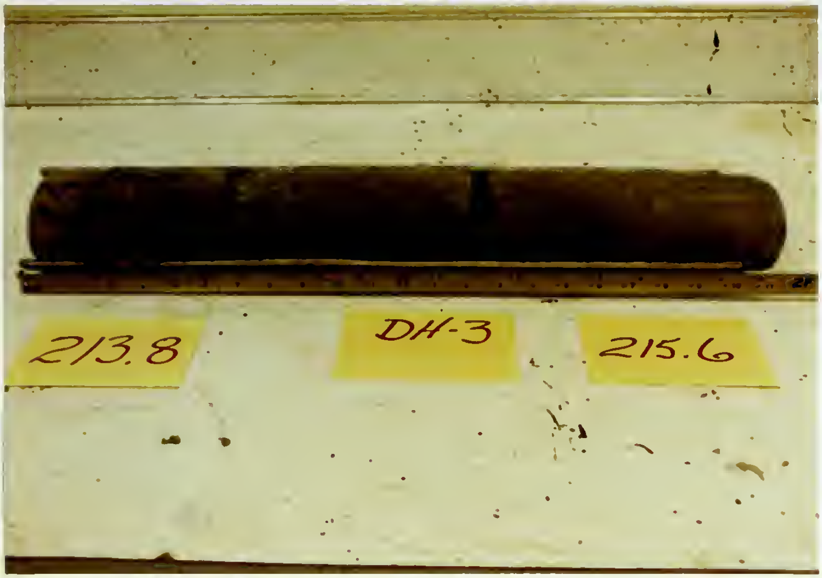
DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET
410	SANDSTONE: Light gray, very fine grained, argillaceous, with thin coal and claystone seams.	99	86	410-429
420	CLAYSTONE; Dark gray, soft rock, thinly laminated, coal seams, slickensides, thin broken zones.			
435–437	MISSING - Lost core	80	15	429-443
	SANDSTONE; Gray, fine grained, thin claystone seams.			
444	CLAYSTONE: Gray, laminated, sandy layers.	100	51	443-450.5
450.5	Bottom of Hole			

GEOMECHANICAL

DEGREE OF WEATHERING	JOINTS/FT	DISCONTINUITIES TYPE	DISCONTINUITIES DIP
Broken Rock to 411'			
SW	3	BJ CF	18°
SW	1	BJ	
SW	1	BJ	
SW	2	OJ	10°
MW	2	OJ	60°
MW	1	CJ	50°
MW	9	OJ	52°
F	3	BJ	0°
F	1	CJ	75°


210.0
DH-3
211.8


211.8
DH-3
213.8


213.8
DH-3
215.6

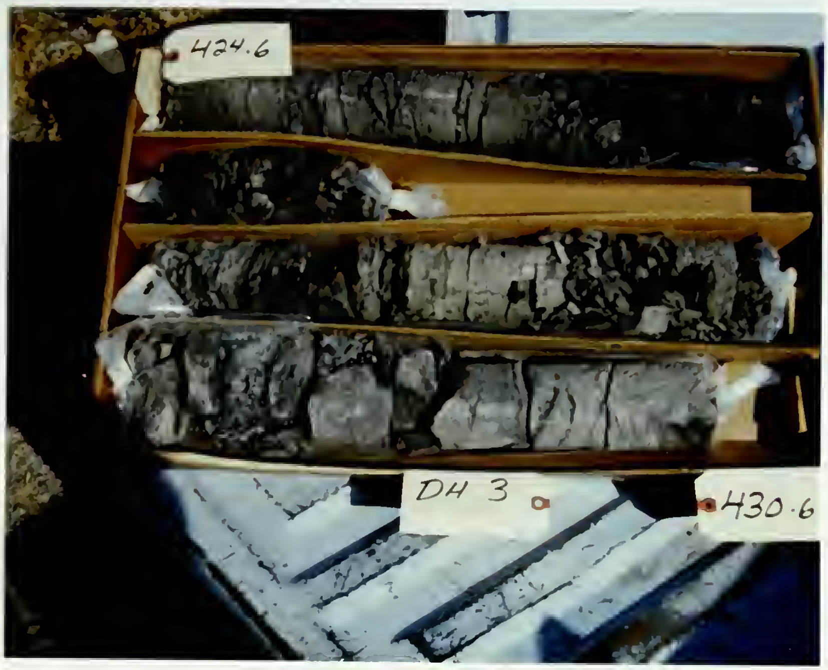

215.6
DH-3
217.3


Red Lodge
DH-3
220.9 - 222.9


Red Lodge
DH-3
222.9 - 225.3


410.0
DH 3
417.2


4172
DH 3
424 6


424.6
DH 3
430.6


430 6
DH 3
441 0


441.0
DH 3
448.8


448. 8
DH 3
450.5

Northern Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH-5

SHEET 1 OF 3

DRILL TYPE: SOIL / ROCK: Bucyrus Erie	CLIENT: State of Montana AMR Program
SIZE, TYPE OF BIT: 7-7/8" Tricone	PROJECT: Red Lodge/Bearcreek
CASING: SIZE 7" LENGTH 57.5'	LOCATION: Washoe Sloped Entry, North Side Highway 308
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — Disturbed / Undisturbed	ELEVATION: TOP OF HOLE 4979* — GROUNDWATER 18.0'
TOTAL NO. CORE BOXES: N/A — TOTAL CORE RECOVERY FOR BORING (%): N/A	THICKNESS OF OVERBURDEN, FT. 47.0' — DEPTH DRILLED INTO ROCK, FT. 204.0 — TOTAL DEPTH OF HOLE, FT. 251.0
REMARKS: *Elevation interpolated from topographic map.	STARTED 7-14-87 — COMPLETED 7-16-87
	DRILLED BY: B. Kupfner
	LOGGED BY: R. Dombrouski

DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
0.3	TOPSOIL				
18	GWL (7-16-87)				
	Lean CLAY; Stiff, moist to saturated, dark brown.				
45					
47	Clayey GRAVEL				
60	CLAYSTONE; Dark gray, soft rock, thinly bedded, occasional thin sandstone and coal layers.				
80	(continued......)				

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-5 SHEET 2 OF 3

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	BLOWS/FOOT
80		CLAYSTONE; dark gray, soft rock, thinly bedded, occasional thin sandstone and coal layers.				
100						
105		SANDSTONE; Dark gray, fine grained, moderately cemented, argillaceous.				
125		CLAYSTONE; Dark gray, soft to moderately hard rock, thinly laminated, occasional thin sandstone seams.				
140						
155		SANDSTONE; Dark gray, fine grained, moderately cemented, argillaceous.				
160						
169		CLAYSTONE; Dark gray, moderately hard to hard rock, numberous thin sandstone and coal layers.				
180						
		(continued.....)				

NET 122E

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-5 SHEET 3 OF 3

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	BLOWS/FOOT
190						
200						
		CLAYSTONE; Dark gray, moderately hard to hard rock, numerous thin sandstone and coal layers.				
220						
237		COAL				
245		SANDSTONE; Dark gray, fine grained, argillaceous, moderately cemented.				
251		Bottom of Hole				

NET 122E

Northern Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

HOLE NO. DH-6

JOB NO. 87-3001.D

SHEET 1 OF 3

DRILL TYPE: SOIL / ROCK Schramm Air Drill	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 7-7/8 Tricone	PROJECT Red Lodge/Bearcreek
CASING: SIZE 7" LENGTH 46.7'	LOCATION Washoe Mine Highway 308 South of 4-Mile Marker
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — Disturbed / Undisturbed	ELEVATION: TOP OF HOLE Not Determined; GROUNDWATER 19
TOTAL NO. CORE BOXES / TOTAL CORE RECOVERY FOR BORING (%)	THICKNESS OF OVERBURDEN, FT. 38'; DEPTH DRILLED INTO ROCK, FT. 228; TOTAL DEPTH OF HOLE, FT. 226
REMARKS	STARTED 7/16/87; COMPLETED 7/16/87
	DRILLED BY Bill Kupfner
	LOGGED BY R. Dombrouski

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
0.3		TOPSOIL				
		Lean CLAY; stiff, moist to saturated, dark gray.				
19		GWL (7/16/87)				
31		Poorly Graded GRAVEL with Clay; dense, saturated.				
38		CLAYSTONE; dark gray, modeately hard rock, laminated, occasional sandstone layers.				
55		SANDSTONE; gray, hard rock, well cemented, very fine grained, argillaceous.				
80		(continued ....)				

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D   HOLE NO. DH-6   SHEET 2 OF 3

DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R Q D	DEPTH, FEET	BLOWS/FOOT
80	SANDSTONE; gray, hard rock, well cemented, very fine grained, argillaceous.				
100					
120					
141	COAL				
144	SANDSTONE				
151	COAL				
154					
160	SANDSTONE; light gray, moderately hard rock, well cemented, fine grained, occasional claystone and coal layers.				
180					
	(continued ....)				

NET 122E

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D HOLE NO. DH-6 SHEET 3 OF 3

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	RQD	DEPTH, FEET	BLOWS/FOOT
190		CLAYSTONE; gray, moderately hard rock, thinly laminated, some carbon detritus.				
200						
215		SANDSTONE; light gray, moderately hard rock, well cemented.				
230		COAL				
236		SANDSTONE; gray, moderately well cemented, argillaceous.				
260						
266		Bottom of Hole				

NET 122E

Northern Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH-7,7A,7B

SHEET 1 OF 1

DRILL TYPE: SOIL / ROCK Schramm Air Drill	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 6-1/4" Tricone	PROJECT Red Lodge/Bearcreek
CASING: SIZE 7" LENGTH 7'	LOCATION Smith Mine; Mapped Entry west of entry into Red Lodge Coal Co.
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — Disturbed / Undisturbed	ELEVATION: TOP OF HOLE; GROUNDWATER Not Encountered
TOTAL NO. CORE BOXES N/A; TOTAL CORE RECOVERY FOR BORING (%) N/A	THICKNESS OF OVERBURDEN, FT.; DEPTH DRILLED INTO ROCK, FT.; TOTAL DEPTH OF HOLE, FT.
REMARKS	STARTED 7/17/87; COMPLETED 7/17/87
	DRILLED BY Paul
	LOGGED BY R. Dombrouski

DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
0.5	TOPSOIL				
	FILL; Lean Clay; firm to stiff, moist, claystone fragments, brown.				
16	COAL				
22	SANDSTONE; light gray, hard rock, very fine grained.				
39	Bottom of Hole				

NET 122D

Northern
Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH-8
SHEET 1 OF 1

DRILL TYPE: SOIL ROCK Schramm Rotadrill	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 6-1/4" Tricone	PROJECT Red Lodge/Bearcreek
CASING: SIZE 7" LENGTH 7'	LOCATION South Highway 308; Unmapped Smith Mine Adit; E of Entry into Red Lodge Coal Co.
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN Disturbed / Undisturbed	ELEVATION: TOP OF HOLE Not Determined / GROUNDWATER 52
TOTAL NO. CORE BOXES / TOTAL CORE RECOVERY FOR BORING (%)	THICKNESS OF OVERBURDEN, FT. / DEPTH DRILLED INTO ROCK, FT. / TOTAL DEPTH OF HOLE, FT.
REMARKS	STARTED 7/17/87 / COMPLETED 7/17/87
	DRILLED BY R. Dombrouski
	LOGGED BY R. Dombrouski

DEPTH, FT.	LEGEND	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
2.0		Lean CLAY				
20		CLAYSTONE; brown to gray, soft rock, weakly cemented.				
40						
52		GWL (7/17/87)				
62		COAL				
68.5		CLAYSTONE				
70		Bottom of Hole				

NET 122D

Northern Engineering and Testing, Inc.

LOG OF EXPLORATION BORING

JOB NO. 87-3001.D

HOLE NO. DH-9

SHEET 1 OF 1

DRILL TYPE: SOIL / ROCK Bucyrus Erie	CLIENT State of Montana AMR Program
SIZE, TYPE OF BIT 6-1/4" Tricone	PROJECT Smith Mine
CASING: SIZE 7" LENGTH 10'	LOCATION South Highway, 16' east of DH-8 87° inclination void 13.5' east of DH-8
TOTAL NO. OF OVERBURDEN SAMPLES TAKEN 0	
Disturbed 0 / Undisturbed 0	ELEVATION: TOP OF HOLE Not Determined / GROUNDWATER 50
TOTAL NO. CORE BOXES / TOTAL CORE RECOVERY FOR BORING (%)	THICKNESS OF OVERBURDEN, FT. 26 / DEPTH DRILLED INTO ROCK, FT. 44.0 / TOTAL DEPTH OF HOLE, FT. 70.0
REMARKS	STARTED 8/04/87 / COMPLETED 8/04/87
	DRILLED BY B. Kupfner
	LOGGED BY R. Dombrouski

DEPTH, FT.	CLASSIFICATION OF MATERIALS	% CORE RECOVERY	R.Q.D.	DEPTH, FEET	BLOWS/FOOT
2.0	Lean CLAY				
	CLAYSTONE; light brown to dark gray; very soft rock to 26 feet, then moderately hard, moderately cemented.				
20					
40					
50	GWL (8/04/87)				
54	SANDSTONE; gray, hard rock				
57.8	VOID				
66.5	Bottom of Hole				

NET 122D

APPENDIX B

Northern Engineering and Testing, Inc.

STANDARD COMPUTATION SHEET

PROJECT: [illegible]

JOB NO. 87-3001.D-5

PURPOSE: Roof Analysis : #1½ seam DH-1

SHEET 1 OF 4

COMPUTED BY: [illegible]

CHECKED BY: JP

DATE: 8-25-87

DH 1 V. thin interbedded sandstone and shales (immediate roof)

V. Large Alluvial Gravel
γ = 145 lbs/ft³

Comments

90'

110

Lean CLAY to Claystone
V. soft rx, little strength
γ = 105 lb/ft³

100'

Argillaceous SANDSTONE, Med Hard Rx
γ = 150 lbs/ft³
[illegible] thick E = [illegible] psi
tensile [illegible] psi

103'

110' V. thin interbedded shale with sandstone (Banded)
15' thick, RMR Poor Rx [illegible]
E_m [illegible] ; 8.455×10^5 [illegible]
γ 140 lbs/ft³ q_u = 435 psi
c [illegible] psi
ϕ - [illegible]°
E = [illegible] psi

120'

125'

125.7

L = 22'

X = 0' - 22'

Room
Void

Northern
Engineering and Testing, Inc.

STANDARD COMPUTATION SHEET

PROJECT ______ JOB NO. ______

PURPOSE ______ SHEET 2 OF 4

COMPUTED BY ______ CHECKED BY ______ DATE ______

Example Opening Span 22' ; 91' gravel overburden ; 10' clay $\gamma = 105$

a) Shale beam : 18' thick $E = 1 \times 10^6$ psi tensile strength 300 psi
$\gamma = 140$ lb/ft³

b) Sandstone beam : 7' thick $E = 5 \times 10^6$ psi tensile strength 500 psi
$\gamma = 150$ lbs/ft³ w/ 91' gravel overburden + 10' clay overburden

1) Assume no tensile strength btwn bedding calc deflections, is self loading?

Shale beam

$$q = 140\,\text{lbs/ft}^3 (18') \cdot 1' = 2520 \text{ lbs / ft. length}$$

$$I = \frac{bH^3}{12} = \frac{1(18)^3}{12} = 486 \qquad \text{Max defl. } x = L/2$$

$$\text{deflection } W = \frac{q x^2 (L-x)^2}{24EI} \quad : \quad w = \frac{q \frac{L^2}{4} \left(\frac{L}{2}\right)^2}{24EI}$$

$$W = \frac{2520 \left(\frac{22^2}{4}\right)\left(\frac{22}{2}\right)^2}{24\left(1 \times 10^6 \text{psi} \cdot \frac{144 \text{psi}}{\text{ft}^2}\right)(486)} = 2.1966 \times 10^{-5} \text{ ft}$$

Sandstone beam w/ weight of clay and gravel overburden

$$q = 91' \cdot 145 \text{ lbs/ft}^3 + 10' \cdot 105 \text{ lb/ft}^3 + 7' \cdot 150 \text{ lbs/ft}^3 \cdot 1 = 15295 \text{ lbs/ft beam}$$

$$I = \frac{1(7)^3}{12} = 28.58\overline{3} \qquad \text{defl at } x = L/2$$

$$W = \frac{q \frac{L^2}{4} \left(\frac{L}{2}\right)^2}{24EI}$$

$$W = \frac{15295 \text{ lbs} \left(\frac{22^2}{4}\right)\left(\frac{22}{2}\right)^2}{24\left(5 \times 10^6 \text{psi} \cdot 144 \text{psi/ft}\right)(28.583)} = 4.5 \times 10^{-4} \text{ ft}$$

Sandstone beam deflects more than shale beam so beams are self loading to act as composite

For this condition if there is no slippage between bedding plane can analyze problem as simple composite beam

* If sliding occurs between bedding planes and sandstone and shale then :

$$\frac{M}{EI_{shale}} = \frac{q\left(L^2 - 6Lx + 6x^2\right)}{\left[E_{sh} t_{sh}^3 + E_{sstn} t_{sstn}^3\right]} \qquad \text{with max tension at } x = 0 \text{ } L = 0$$

where ...

Will SHALE fail in tension ?

Northern Engineering and Testing, Inc.

STANDARD COMPUTATION SHEET

PROJECT ______________________ JOB NO. ________

PURPOSE ______________________ SHEET 3 OF 4

COMPUTED BY ____________ CHECKED BY ____________ DATE ________

$$\frac{M}{(1.44\times10^{5})(486)} = \frac{\overset{q}{17815 \text{ lb}}\,(22^2 - 0 + 0)}{[\,1.44\times10^{5}(16)^2 + 7.2\times10^{5}(7)^2\,]} \Rightarrow \frac{8622460}{1.086768\times10^{12}}$$

$q = 91'\cdot145 + 10'\cdot105 + 7'\cdot150 + 18'\cdot140 = 17815$ lbs / length beam

$$\frac{M}{6.9984\times10^{7}} = 7.934037\times10^{-6} \qquad M = 555256 \text{ lb-ft}$$

$$\sigma_{max\ tensile} = \frac{Mc}{I} \qquad \sigma_{max\ tensile} = \frac{555256\,(18/2)}{486} = 10282.5 \frac{\text{lb}}{\text{ft}^2} = 71 \text{ psi}$$

$$F.S. = \frac{300 \text{ psi lab tensile strength}}{71 \text{ psi beam}} = 4.2$$

In case of Shale beam self loading only, that is shale deflects more than sandstone above producing bed separation between the two; then Tensile failure analysis is

$$\sigma_{max\ tensile} = \frac{qL^2}{2bh^2}$$

$q = 140 \text{ lbs/ft}^3 \cdot 18\cdot1' = 2520$ lbs / ft length

$$\sigma_{max_t} = \frac{2520\,(22)^2}{2\cdot1\cdot18^2} = 1882 \text{ lbs/ft}^2 \text{ or } 13.1 \text{ psi}$$

$$F.S. = \frac{300 \text{ psi}}{13.1} = 23$$

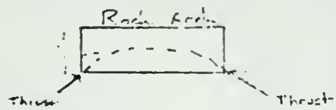
Northern Engineering and Testing, Inc.

STANDARD COMPUTATION SHEET

PROJECT Red Lodge / Bearcreek — JOB NO. ____

PURPOSE Analyse According to Cox w/ Voussoir Arch for Compressional and Shear Failure — SHEET 4 OF 4

COMPUTED BY ____ CHECKED BY ____ DATE ____



1) Consider shale beam 18 ft. thick with 125' of rock & overburden, span 22'
q_u = 435 psi assumed No-cohesion along bedding = S_o
ϕ = 30°

Compression:

$H = \frac{\gamma h L^2}{5\,3/4\, t}$ where from above γh = 17815 lbs/ft²
t = Beam thickness

$H = \frac{17815(22)^2}{5\,3/4\,(18)} = 79337.6$ lbs/ft = ~~56...~~

$c = \frac{H}{t/4}$ $c = \frac{79337.6}{18/4} = 17741.7$ lbs/ft² or 123 psi

c = max stress in beam

$FS = \frac{435}{123} = 3.5$ → For Compressional failure

Calc minimum thickness beam required for stability

$t = \sqrt{\frac{\gamma h L}{3/2\, c}}$ where c = max. compressive stress in beam

$t = \sqrt{\frac{17815\,\text{psf}\,(22)}{3/2\,(435\,\text{psi})(144\,\text{psi/psf})}}$ $t = 9.6'$

$FS = \frac{18}{9.6} = 1.9$

Shear Failure:

$V = \frac{\gamma h L}{\frac{-}{t/4}}$ $V = \frac{17815(22)}{\frac{-}{18/4}} = 43547.8$ lbs/ft²

$S = S_o + \sigma \tan\phi$ $S = 0 + 17741.7 \tan 30° = 10243.2$ psf mobilized

Same as ($\tau = c + \sigma_n \tan\phi$)

$FS = \frac{10243.2}{43547.8} = 0.23$ which indicates arching forces don't always prevent minor block falls in roof.

$FS = \frac{\text{Resisting Force}}{\text{Driving Force}}$

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No.1 1/2 Seam at D#-1
Room Size, ft. = 22

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(D203)
1	145	5			0.00E+00	0.0	#DIV/0!	1.32E+04
2	125	10			#DIV/0	0.0	#DIV/0!	1.42E+04
3	150	7	4E+05	350	3.87E-03	11.8	0.8	1.53E+04
4	140	15	4E+05	350	3.73E-05	32.4	4.9	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No.1 1/2 Seam at DH-1
Room Size, ft.= 35

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(CODE)
1	145	5.			0.00E+00	0.0	#DIV/0!	1.33E+04
2	125	12			#DIV/0!	0.7	#DIV/0!	1.42E+04
3	150	7	4E+05	350	9.45E-03	7.5	0.5	1.53E+04
4	140	13	4E+05	350	9.15E-05	20.7	3.1	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No.1 1/2 Seam at DH-1
oom Size, Ft.= 30

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(C2D3)
1	145	51			0.00E+00	0.0	#DIV/0!	1.33E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	4E+05	350	1.96E-03	5.2	2.4	1.53E+04
4	140	18	4E+05	350	1.92E-04	14.4	2.2	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No.1 1/2 Seam at DH-1
Room Size, ft.= 35

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(DEC3)
1	145	91			0.00E+00	0.0	#DIV/0	1.33E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	130	7	4E+05	350	3.63E-03	3.8	0.3	1.53E+04
4	140	13	4E+05	350	3.52E-04	10.6	1.5	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No.1 1/2 Seam at D--1
oom Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(DEC3)
1	143	91			0.00E+00	0.0	#DIV/0	1.33E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	152	7	4E+05	175	3.67E-03	5.9	0.4	1.53E+04
4	140	18	4E+05	175	3.75E-05	16.1	2.4	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No.1 1/2 Seam at DH-1
Room Size, Ft. = 25

Layer No.	Unit weight pcf	Layer Thickness Ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(C2C3)
1	145	51			0.00E+00	0.0	#DIV/0!	1.32E+04
2	125	12			#DIV/0!	0.0	#DIV/0!	1.48E+04
3	150	7	4E+05	175	9.45E-03	3.8	0.3	1.53E+04
4	140	15	4E+05	175	5.15E-05	10.4	1.5	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No.1 1/2 Seam at DH-1
oom Size, ft.= 30

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(C2:C3)
1	145	5.			0.00E+00	0.0	#DIV/0!	1.32E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	4E+05	175	1.96E-02	2.6	0.2	1.53E+04
4	140	18	4E+05	175	1.90E-04	7.2	1.1	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No.1 1/2 Seam at D--1
oom Size, ft.= 35

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(DEDB)
1	145	5.			0.00E+00	0.0	#DIV/0!	1.32E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	4E+05	175	3.63E-02	1.9	0.1	1.53E+04
4	140	18	4E+05	175	3.52E-04	5.3	0.8	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No.1 1/2 Seam at DH-1
Room Size, ft.= 20

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(C2C3)
1	145	51			0.00E+00	0.0	#DIV/0!	1.32E+04
2	135	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	4E+05	65	3.87E-03	3.0	0.2	1.53E-04
4	140	18	4E+05	88	3.75E-05	8.1	1.2	1.78E-04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No.1 1/2 Seam at B-1
Room Size, ft.= 25

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(CEDD)
1	145	51			0.00E+00	0.0	#DIV/0!	1.33E+04
2	125	12			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	4E+05	56	9.45E-03	1.9	0.1	1.53E+04
4	140	18	4E+05	88	9.15E-05	5.1	6.5	1.73E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No.1 1/2 Seam at D-1
oom Size, Ft.= 30

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(DEQ3)
1	145	91			0.00E+00	0.0	#DIV/0!	1.30E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	4E-05	88	1.55E-02	1.3	0.1	1.53E+04
4	140	18	4E+05	58	1.90E-04	3.5	0.5	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No.1 1/2 Seam at D-1
pan Size, ft.= 30

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(DEC3)
1	145	51			0.00E+00	0.0	#DIV/0!	1.32E+04
2	125	10			#DIV/0!	0.0	#DIV/0!	1.42E+04
3	150	7	2E+05	350	7.74E-03	11.8	0.6	1.53E+04
4	140	10	1E+05	350	7.50E-05	32.4	4.9	1.78E+04

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

===

roblem Description: No.1 1/2 Seam at DH-1
oom Size, ft.= 32

===

ayer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure	SUM(CBCD)
1	145	51			2.22E+22	0.0	#DIV/0	1.32E+04
2	125	.2			#DIV/0	0.0	#DIV/0	1.42E+04
3	150	7	1E+05	350	1.55E-02	11.8	0.6	1.53E+04
4	140	.8	1E+05	350	1.50E-04	33.4	4.9	1.78E+04

===

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: Seam No. 2 at Dr-1
oom Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	141	.01	0E+00	0	0.00E+00	0.0	#DIV/0!
2	63	25	0E+00	0	#DIV/0!	0.0	#DIV/0!
3	63	126	4E+05	350	1.74E-05	327.9	116.3
4	63	10	4E+05	350	7.32E-05	32.4	1216.2

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: Seam No. 3 at D-1
oom Size, ft.= 25

aver No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	141	101	0E+00	0	0.00E+00	0.0	#DIV/0!
2	53	25	0E+00	0	#DIV/0!	0.0	#DIV/0!
3	83	108	4E+05	350	4.25E-06	225.9	74.4
4	83	10	4E+05	350	1.75E-04	19.4	778.7

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: Seam No. 2 at DH-1
oom Size, ft.= 30

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	141	101	0E+00	0	0.00E+00	0.0	#DIV/0
2	83	25	0E+00	0	#DIV/0!	0.0	#DIV/0!
3	83	106	4E+05	350	6.83E-05	145.7	51.7
4	83	10	4E+05	350	3.65E-04	12.5	540.3

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: Seam No. 3 at D-1

oom Size, ft. = 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	141	101	0E+00	0	0.00E+00	0.0	#DIV/0!
2	83	25	0E+00	0	#DIV/0!	0.0	#DIV/0!
3	83	106	4E+05	250	1.74E-05	327.9	116.3
4	83	5	4E+05	350	2.88E-04	15.2	2471.1

RED LODGE / BEARCREEK SUBSIDENCE STUDY

Roof Collapse Analysis

roblem Description: Seam No. 2 at D--1

oom Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	141	101	0E+00	0	0.00E+00	0.0	#DIV/0
2	83	25	0E+00	0	#DIV/0!	0.0	#DIV/0
3	83	100	4E+05	350	1.74E-06	337.5	116.3
4	83	2	4E+05	350	1.80E-03	6.1	6237.7

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: Seam No. 2 at D4-1
Room Size, ft.= 25

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	141	101	0E+00	0	0.00E+00	0.0	#DIV/0!
2	83	25	0E+00	0	#DIV/0!	0.0	#DIV/0
3	83	108	4E+05	350	4.25E-06	203.5	74.4
4	83	1	4E+05	350	1.75E-03	1.9	8010.4

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at D-3
Room Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	150	0E+00	0	0.00E-00	0.0	#DIV/0!
2	67	104	4E+05	350	1.85E-05	321.2	113.6
3	52	14	7E+05	600	2.26E-05	76.2	894.1
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at D--3
Room Size, ft.= 25

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	53	.50	0E+00	0	0.00E+00	0.0	#DIV/0
2	87	104	4E+05	350	4.52E-05	193.2	73.7
3	92	14	7E+05	550	5.56E-05	48.7	572.3
4					#DIV/0!	#DIV/0!	#DIV/0

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at D--3
Room Size, ft.= 30

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	55	182	0E+00	2	0.00E+00	0.0	#DIV/0!
2	87	104	4E+05	350	9.37E-05	133.5	50.5
3	90	14	7E+05	680	1.15E-04	33.6	397.4
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 4 Seam at D--3
oom Size, Ft.= 40

Layer No.	Unit Weight pcf	Layer Thickness Ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	152	0E+00	0	0.00E+00	0.0	#DIV/0!
2	97	104	4E+05	350	2.55E-05	75.3	28.4
3	50	14	7E+05	650	3.64E-04	15.0	223.5
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 4 Seam at D--3
oom Size, ft.= 30

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	33	102	0E+00	0	0.00E+00	0.0	#DIV/0
2	67	104	4E+04	350	1.65E-05	301.2	113.5
3	90	14	7E+04	680	2.38E-04	76.2	894.1
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

===

Problem Description: No. 4 Seam at D-3
Room Size, ft.= 30

===

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	83	152	2E+00	0	0.00E+00	0.0	#DIV/0!
2	87	124	4E+04	175	1.85E-05	150.5	56.6
3	92	14	7E+04	600	2.28E-04	76.2	834.1
4					#DIV/0!	#DIV/0!	#DIV/0!

===

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 4 Seam at D--2
oom Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	190	0E+00	0	0.00E+00	0.0	#DIV/0!
2	57	104	4E+04	350	1.85E-05	301.5	113.6
3	52	14	7E-04	342	2.36E-04	36.1	447.1
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at DH-3
Room Size, ft.= 20

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	180	0E+00	0	0.00E-00	0.0	#DIV/0
2	57	124	4E+04	175	1.85E-05	150.6	56.8
3	50	14	7E+04	340	2.35E-04	36.1	447.1
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at DH-3
Room Size, Ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	.80	0E+00	0	0.00E+00	0.0	#DIV/0!
2	67	104	4E+04	175	5.37E-05	66.9	25.1
3	90	3	7E+04	342	2.51E-02	3.6	56.2
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at D--3
Room Size, Ft.= 32

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	162	0E+00	0	0.00E+00	0.0	#DIV/0
2	67	124	4E+04	175	9.37E-05	65.9	25.5
3	52	2	7E-04	340	5.65E-02	2.4	1446.9
4					#DIV/0	#DIV/0	#DIV/0

RED LODGE BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 4 Seam at DH-3
oom Size, ft.= 30

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	162	0E+00	0	0.00E+00	0.0	#DIV/0
2	57	104	4E+04	175	9.372E-05	66.5	35.3
3	50	1	7E+04	340	2.25E-0[illegible]	1.3	2924.5
4					#DIV/0!	#DIV/0!	#DIV/0

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 4 Seam at DH-3
Room Size, ft.= 30

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	63	152	0E+00	0	0.00E+00	0.0	#DIV/0!
2	57	124	4E+04	350	9.37E-05	133.9	50.5
3	52	1	7E+04	650	2.26E-01	2.4	5829.2
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 5 Seam at DH-3
Room Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	323	0E+00	0	0.00E+00	0.0	#DIV/0!
2	83	182	4E+05	350	4.93E-07	552.6	243.7
3	53	10	4E+05	270	8.07E-05	20.9	3331.1
4	93	15	3E+05	150	7.17E-05	17.4	1.1

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 5 Seam at DH-3
oom Size, ft.= 35

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	84	335	0E+00	0	0.00E+00	0.0	#DIV/0!
2	63	.33	4E+05	350	1.20E-05	353.7	155.3
3	53	12	4E+05	270	1.57E-04	13.4	2131.9
4	53	15	2E+05	150	1.75E-04	11.1	0.7

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 5 Seam at DH-3
Room Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	84	222	0E+00	0	0.00E+00	0.0	#DIV/0!
2	83	158	4E+05	350	1.52E-05	145.5	128.0
3	53	10	4E+05	270	4.25E-04	7.3	1480.1
4	53	15	3E+05	150	3.63E-04	7.7	0.5

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 5 Seam at DH-3
oom Size, ft.= 35

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	223	2E-02	0	0.00E+00	0.0	#DIV/0!
2	60	182	4E-05	352	4.52E-05	100.4	78.2
3	93	13	4E-05	270	7.57E-04	5.3	1237.7
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 5 seam at B--3
oom Size, ft.= 20

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	146	333	2E+02	2	0.00E+00	0.0	#DIV/0
2	145	182	4E+06	350	5.59E-07	316.3	135.9
3	155	.2	4E+05	270	1.34E-04	12.5	1914.-
4	155	.5	2E+05	150	1.20E-04	10.5	0.6

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 5 seam at 24-3
Room Size, ft.= 20

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	145	336	2E-00	0	0.00E-00	0.0	#DIV/0!
2	145	188	4E+05	350	8.59E-07	315.3	135.5
3	155	10	4E+05	270	1.34E-04	13.5	1914.4
4	155	15	2E+05	250	1.20E-04	17.4	1.0

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 5 seam at DH-3
oom Size, ft.= 35

Layer No.	Unit weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	146	225	0E+00	0	0.00E+00	0.0	#DIV/0
2	145	132	4E+05	330	8.26E-06	100.3	45.7
3	155	10	4E+05	270	1.26E-03	4..	625.1
4	155	15	2E+05	150	1.12E-03	3.4	0.2

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 5 Seam at D--3
oom Size, Ft.= 30

ayer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection Ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	286	0E+00	0	2.00E+00	0.0	#DIV/0
2	80	182	4E+04	350	4.[illegible]E-0[illegible]	182.4	73.5
3	53	12	4E+04	270	7.57[illegible]E-0[illegible]	0.6	1287.7
4					#DIV/0!	#DIV/0	#DIV/0.

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 5 Seam at D4-2
Room Size, ft.= 35

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	226	0E+00	0	0.00E+00	0.0	#DIV/0!
2	83	132	4E+04	175	4.60E-05	58.3	19.6
3	53	10	4E+04	135	7.57E-03	3.4	546.1
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

roblem Description: No. 3 Seam at B4-3
oom Size, ft.= 15

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	220	0E+00	0	0.00E+00	0.0	#DIV/0!
2	63	182	4E+05	350	1.02E-02	333.7	155.5
3	63	5	4E+05	270	7.85E-04	5.7	4382.0
4					#DIV/0!	#DIV/0!	#DIV/0!

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 3 Seam at DH-3
Room Size, ft.= 25

Layer No.	Unit Weight pcf	Layer Thickness ft.	E psi	Tensile Strength psi	Individual Layer Deflection ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	225	2E+[illegible]	0	[illegible]	0.0	#DIV/0!
2	53	.52	4E+05	320	1.[illegible]E-0[illegible]	[illegible].7	[illegible].5
3	53	2	4E+05	270	4.[illegible]E-0[illegible]	2.7	[illegible]
4					#DIV/0!	#DIV/0!	#DIV/0!

Northern
Engineering
and Testing, Inc.

STANDARD COMPUTATION SHEET

PROJECT: Red Lodge / Bearcreek JOB NO. 87-3001.D-5

PURPOSE: Coles 1½ seam DH-1 ; Pillar loads SHEET 1 OF 2

COMPUTED BY: ED CHECKED BY: J. Pool DATE: 8-21-87

Pillar # 1

$$P = \frac{(L_p + W_o)(W_p + W_o)\gamma h}{W_p L_p}$$

Seam Ht = 5.5 ft

$L_p = 55'$ } Pillar Dimensions
$W_p = 25'$

$W_o + L_p = 80'$ length of Trib. Area

$\gamma_{crush} = 145$ lb/ft³ · 9.

$\gamma_{rock} = 150$ lb/ft³ · 36'

$W_o + W_p = 42'$ width of Trib. Area

$P = \frac{(80)(42) \cdot 18595}{25 \cdot 55} = 45440$ lbs/ft² or 315.6 psi

Pillar # 2

$L_p = 55'$
$W_p = 32'$
$L_p + W_o = 80'$
$W_p + W_o = 55'$
$\gamma H = 18595$

$P = \frac{(80)(55) \cdot 18595}{55 \cdot 32} = 49393$ lbs/ft² or 343 psi

Pillar # 3

$L_p = 72'$
$W_p = 25'$
$L_p + W_o = 82$
$W_p + W_o = 50$
$\gamma H = 18595$

$P = \frac{(82)(50)(18595)}{72 \cdot 25} = 42355$ lbs/ft² or 294.1 psi

Pillar # 4

$L_p = 115'$
$W_p = 30'$
$L_p + W_o = 125'$
$W_p + W_o = 55'$
$\gamma H = 18595$

$P = \frac{(125)(55)(18595)}{115 \cdot 30} = 37055$ lbs/ft² or 257 psi

Pillar # 5

$L_p = 57'$
$W_p = 31'$
$L_p + W_o = 63'$
$W_p + W_o = 65'$
$\gamma H = 18595$

$P = \frac{(63)(65)(18595)}{57 \cdot 31} = 46513$ lbs/ft² 323 psi

Northern
Engineering and Testing, Inc.

STANDARD COMPUTATION SHEET

PROJECT: Red Lodge / Brunerock   JOB NO. 87-3001-D-5
PURPOSE: Calcs 1½ seam DH-1   SHEET 2 OF
COMPUTED BY: CHECKED BY: DATE: 8-21-87

Pillar #6
$L_p = 55'$
$W_p = 25'$
$L + W_0 = 90'$
$W_p + W_0 = 55'$
$\gamma H = 18595$

$$P = \frac{(90)(55)\,18595}{(25)(85)} = 39378 \text{ lb/ft}^2 \quad \text{or} \quad 273.5 \text{ psi}$$

Pillar #7
$W_p = 45'$
$W_0 + W_p = 53'$
$\gamma H = 18595$

$$P = \frac{(W_0 + W_p)^2\,\gamma h}{W_p^2}$$

$$P = \frac{(53)^2\,18595}{(45)^2} = 25794 \text{ lb/ft}^2 \qquad 179.1 \text{ psi}$$

Strength of coal cubes Ave. 2500 psi
Correction for size of cubes: $k = \sigma_c\sqrt{D} = (2500 \text{ psi})\sqrt{2}$
$k = 3535$

correction size of pillars $\sigma_1 = \frac{k}{6} = \frac{3535}{6} \approx 590 \text{ psi}$

Correction for pillar dimensions $= 0.64 + 0.36\frac{W}{H}$
where W/H = pillar width to height ratio

Pillar No.	Applied Stress, psi	Pillar W/H	Strength of Pillar, psi	Safety Factor
1	316	25/5.5 = 4.6	1355	4.3
2	343	5.8	1541	4.5
3	294	4.6	1300	4.4
4	257	5.5	1546	6.0
5	323	5.6	1567	4.9
6	274	4.6	1355	4.9
7	179	8.2	2119	11.8

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

roblem Description: No.1 1/2 Seam at D-1

oal Qu.(psi) = 2500 Seam Thickness, ft. = 6
u Dia. or Size, in.= 2

ILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS ps.	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	55	25	60	42	18595	315	3.3	3.1	1042
2	55	32	65	53	18595	343	3.6	4.0	1225
3	72	35	82	50	18595	294	3.6	3.1	1047
4	115	30	125	55	18595	257	4.6	3.8	1173
5	57	31	65	65	18595	323	3.7	3.9	1199
6	85	25	90	55	18595	301	3.5	3.1	1040
7	45	45	53	53	18595	179	8.5	5.5	1570
8					18595	#DIV/0!	#DIV/0!	0.0	377
9					18595	#DIV/0!	#DIV/0!	0.0	377
10					18595	#DIV/0!	#DIV/0!	0.0	377
11					18595	#DIV/0!	#DIV/0!	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

==

roblem Description: No.1 1/2 Seam at DH-1

oal Su.(psi) = 2000 Seam Thickness, ft. = 8
u Dia. or Size, in.= 3

==

ILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	55	25	80	42	18595	316	2.6	3.1	832
2	55	32	85	55	18595	343	2.9	4.0	951
3	72	25	62	50	18595	294	2.8	3.1	832
4	115	30	125	55	18595	257	3.6	3.8	933
5	57	31	68	65	18595	323	3.0	3.9	955
6	65	25	90	55	18595	301	2.8	3.1	832
7	45	45	53	53	18595	179	7.0	5.6	1255
8					18595	#DIV/0!	#DIV/0!	0.0	302
9					18595	#DIV/0!	#DIV/0!	0.0	302
10					18595	#DIV/0!	#DIV/0!	0.0	322
11					18595	#DIV/0!	#DIV/0!	0.0	322

==

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.1 1/2 Seam at DH-1.

Coal Su.(psi) = 1500 Seam Thickness, ft. = 8
Su Dia. or Size, in.= 2

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	55	25	80	42	18595	316	2.0	3.1	634
2	55	32	65	55	18595	343	2.1	4.0	735
3	72	25	62	50	18595	294	2.1	3.1	624
4	115	30	125	55	18595	257	2.7	3.8	704
5	57	31	66	55	18595	322	2.2	3.9	719
6	55	25	90	55	18595	321	2.1	3.1	634
7	45	45	53	53	18595	175	5.3	5.6	942
8					18595	#DIV/0!	#DIV/0!	0.0	226
9					18595	#DIV/0!	#DIV/0!	0.0	226
10					18595	#DIV/0!	#DIV/0!	0.0	226
11					18595	#DIV/0!	#DIV/0!	0.0	226

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.1 1/2 Seam at DH-1

Coal Cu.(psi) = 1000 Seam Thickness. ft. = 8
Cu Dia. or Size. in.= 6

PILLAR No.	PILLAR DIMENSIONS Length ft.	PILLAR DIMENSIONS Width ft.	TRIBUTARY AREA Length ft.	TRIBUTARY AREA Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	55	25	60	42	18595	315	1.3	3.1	416
2	55	32	65	55	18595	343	1.4	4.2	492
3	72	25	62	50	18595	294	1.4	3.1	4[illegible]5
4	115	30	125	55	18595	257	1.8	3.8	455
5	57	31	66	65	18595	323	1.5	3.9	480
6	55	25	90	55	18595	331	1.4	3.1	416
7	45	45	53	53	18595	179	3.5	5.6	628
8					18595	#DIV/0!	#DIV/0!	0.0	151
9					18595	#DIV/0!	#DIV/0!	0.0	151
10					18595	#DIV/0!	#DIV/0!	0.0	151
11					18595	#DIV/0!	#DIV/0!	0.0	151

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.3 Seam at D--1

Coal Qu.(psi) =   2500   Seam Thickness, ft. = 8
Qu Dia. or Size, in.=   2

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR w/h RATIO	PILLAR STRENGTH psi
1	66	32	90	55	31422	392	3.1	4.0	1226
2	140	27	49	143	31422	404	2.7	3.4	1093
3	192	25	220	45	31422	450	2.3	3.1	1042
4	60	28	49	65	31422	414	2.7	3.5	1120
5	65	30	52	122	31422	562	2.0	3.2	1173
6	105	25	47	135	31422	527	2.2	3.1	1042
7	58	32	52	90	31422	587	2.0	3.6	1173
8	30	30	47	82	31422	914	1.3	3.8	1173
9	72	20	75	55	31422	643	1.4	2.5	907
10					31422	#DIV/0!	#DIV/0!	0.0	377
11					31422	#DIV/0!	#DIV/0!	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No. 2 Seam at D-1

Coal Su. (psi) = 2500 Seam Thickness, ft. = 8
Lab Dia. or Size, in. = 2

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR w/h RATIO	PILLAR STRENGTH psi
1	88	32	92	55	25200	315	3.9	4.0	1225
2	142	27	143	49	25200	324	3.4	3.4	1253
3	198	23	222	45	25200	361	2.9	3.1	1042
4	62	32	85	45	25200	332	3.4	3.5	1122
5	55	30	108	53	25200	457	2.5	3.5	1173
6	22	23	47	135	25200	433	2.5	3.1	1243
7	53	30	92	53	25200	471	2.5	3.8	1173
8	33	30	33	47	25200	749	1.6	3.8	1173
9	78	22	75	55	25200	515	1.8	2.5	927
10					25200	#DIV/0!	#DIV/0!	0.0	377
11					25200	#DIV/0!	#DIV/0!	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No. 2 Seam at D-1

Coal Su.(psi) = 2200 Seam Thickness, Ft. = 8
Sp Dia. or Size, in.= 2

PILLAR NO.	PILLAR DIMENSIONS Length Ft.	Width Ft.	TRIBUTARY AREA Length Ft.	Width Ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR w/h RATIO	PILLAR STRENGTH psi
1	66	32	92	55	25000	315	3.1	4.0	981
2	140	27	140	49	25000	354	2.7	3.4	874
3	[illegible]	25	222	45	25000	351	2.3	3.1	832
4	52	28	65	49	25000	332	2.7	3.5	895
5	65	30	100	52	25000	467	2.0	3.8	935
6	125	25	47	135	25000	423	2.0	3.1	822
7	58	32	92	53	25000	471	2.0	3.6	935
8	32	33	82	47	25000	749	1.3	3.8	928
9	70	22	75	55	25000	516	1.4	2.3	725
10					25000	#DIV/0!	#DIV/0!	0.0	322
11					25000	#DIV/0!	#DIV/0!	0.0	322

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.4 Seam at DH-2

Coal In situ psi = [illegible]   Seam Thickness, ft. = [illegible]
[illegible] 3

PILLAR NO.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR w/h RATIO	PILLAR STRENGTH psi
1	[illegible]	[illegible]	75	38	31580	470	1.6	[illegible]	755
2	[illegible]	[illegible]	87	45	31582	475	1.8	[illegible]	844
3	72	32	75	45	31560	526	1.5	2.2	821
4	72	32	75	44	31560	517	1.6	2.2	801
5	[illegible]	[illegible]	120	40	31562	649	[illegible]	1.5	655
6	[illegible]	[illegible]	88	44	31560	575	[illegible]	[illegible]	[illegible]
7	72	[illegible]	81	41	31562	674	1.0	1.5	655
8	72	22	82	45	31560	542	1.5	2.2	[illegible]
9					31560	#DIV/0!	#DIV/0	0.0	377
10					31560	#DIV/0!	#DIV/0	0.0	377
11					31560	#DIV/0!	#DIV/0	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No. 4 Seam at D-3

Coal S.. (psi) = 2500 Seam Thickness, ft. = 10
Lab Dia. or Size, in. = 2

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	60	15	75	35	18000	273	2.8	1.6	759
2	30	22	37	45	18000	275	3.1	2.2	844
3	70	20	75	45	18000	306	2.9	2.0	801
4	70	20	75	44	18000	300	2.7	2.0	801
5	50	15	100	40	18000	377	1.8	1.5	695
6	70	15	50	44	18000	391	1.8	1.5	695
7	70	15	51	41	18000	391	1.8	1.5	695
8	70	20	50	45	18000	311	2.6	2.0	801
9					18000	#DIV/0!	#DIV/0	0.0	377
10					18000	#DIV/0!	#DIV/0	0.0	377
11					18000	#DIV/0!	#DIV/0	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.3 Seam at D--3

Coal Cu. (psi) = 2500 Seam Thickness, ft. = 8
Cu Dia. or Side, in.= 3

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR w/h RATIO	PILLAR STRENGTH psi
1	100	23	125	40	70000	1057	0.9	2.9	987
2	125	24	110	45	70000	975	1.0	3.0	1014
3	90	27	95	50	70000	950	1.2	3.4	1053
4	100	28	130	50	70000	916	1.1	3.5	1120
5	55	33	60	45	70000	763	1.6	4.1	1252
6	110	35	135	50	70000	1014	1.1	3.3	1057
7	75	27	65	50	70000	1055	1.0	3.4	1053
8					70000	#DIV/0!	#DIV/0!	0.0	377
9					70000	#DIV/0!	#DIV/0!	0.0	377
10					70000	#DIV/0!	#DIV/0!	0.0	377
11					70000	#DIV/0!	#DIV/0!	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.5 Seam at [illegible]-3

Coal Cu (psi) = 3000 Seam Thickness, ft. = 8
Cu Dia. or Size, in.= 3

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	132	33	135	46	40900	517	1.6	3.9	557
2	125	34	[illegible]	45	40900	570	1.8	3.2	1014
3	52	27	55	50	40900	555	2.0	3.4	1093
4	123	33	137	50	40900	535	2.1	3.5	1120
5	53	33	52	45	40900	447	2.9	4.1	1253
6	[illegible]	35	128	52	40900	592	1.8	3.3	1257
7	75	27	63	52	40900	634	1.8	3.4	1093
8					40900	#DIV/0!	#DIV/0!	0.0	377
9					40900	#DIV/0!	#DIV/0!	0.0	377
10					40900	#DIV/0!	#DIV/0!	0.0	377
11					40900	#DIV/0!	#DIV/0!	0.0	377

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.3 Seam at B-3

Coal Uc (psi) = 3000 Seam Thickness, ft. = 6
Specimen Dia. or Size, in.= 2

PILLAR No.	PILLAR DIMENSIONS Length ft.	Width ft.	TRIBUTARY AREA Length ft.	Width ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR W/H RATIO	PILLAR STRENGTH psi
1	100	23	105	45	40900	617	1.3	2.5	790
2	105	24	110	45	40900	572	1.4	3.2	811
3	90	27	95	50	40900	555	1.5	3.4	874
4	125	28	133	50	40900	535	1.7	3.5	895
5	52	33	62	45	40900	447	2.2	4.1	1000
6	113	25	120	50	40900	592	1.4	3.3	853
7	75	27	85	50	40900	634	1.4	3.4	874
8					40900	#DIV/0!	#DIV/0!	0.0	300
9					40900	#DIV/0!	#DIV/0!	0.0	300
10					40900	#DIV/0!	#DIV/0!	0.0	300
11					40900	#DIV/0!	#DIV/0!	0.0	300

RED LODGE / BEARCREEK SUBSIDENCE STUDY
Column Crushing Analysis

Problem Description: No.5 Seam at D4-3

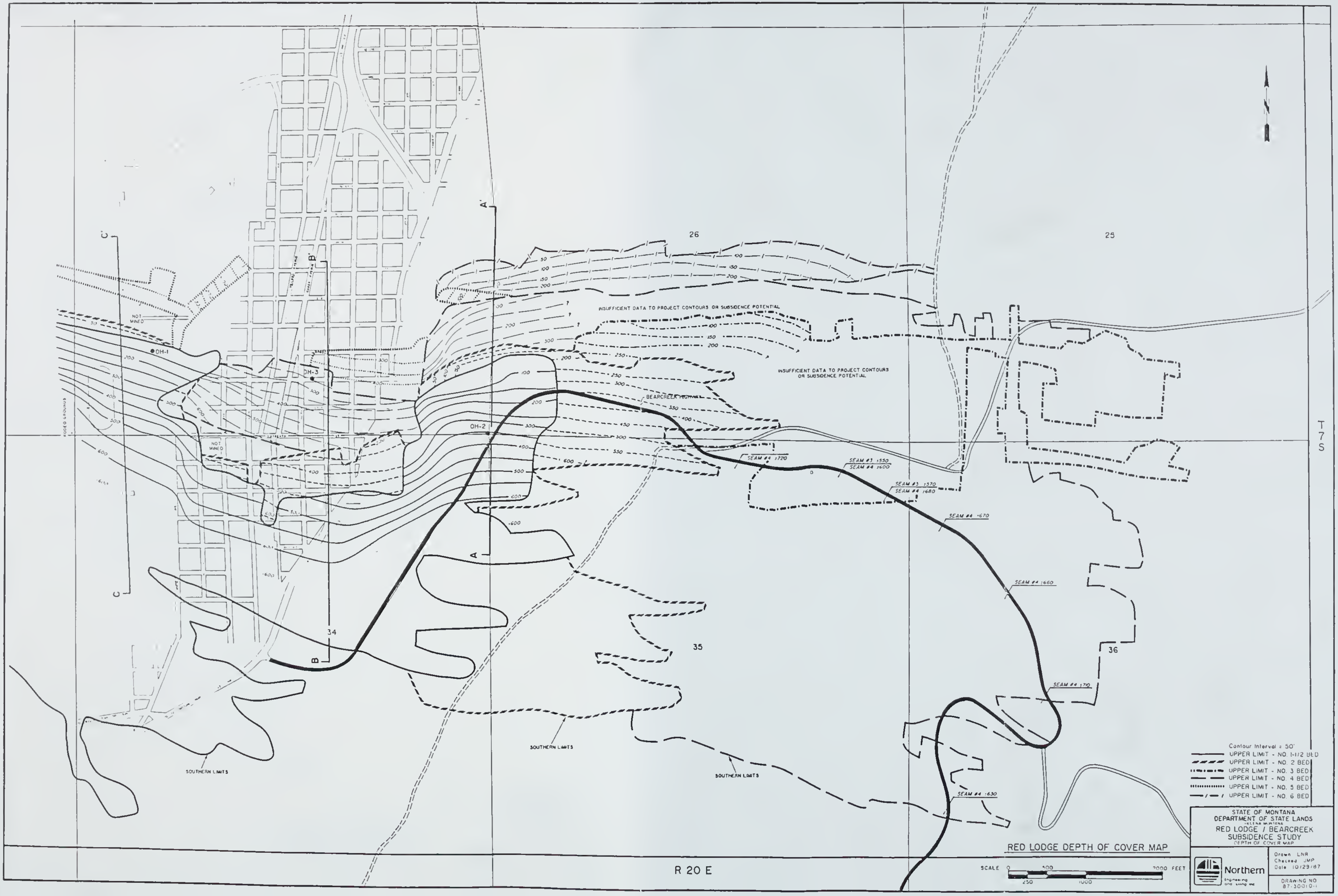
Coal Cu.,psi = 1500 Seam Thickness, Ft. = 6
Cu Dia. of Cube, in.= 2

PILLAR No.	PILLAR DIMENSIONS Length Ft.	Width Ft.	TRIBUTARY AREA Length Ft.	Width Ft.	OVERBURDEN STRESS psf	PILLAR STRESS psi	SAFETY FACTOR	PILLAR w/h RATIO	PILLAR STRENGTH psi
1	100	23	125	43	40920	517	1.0	2.5	552
2	103	24	112	45	42920	572	1.1	3.2	623
3	92	27	95	52	40920	555	1.2	3.4	656
4	123	28	135	50	40920	535	1.3	3.5	672
5	52	33	82	45	40920	447	1.7	4.1	751
6	113	35	111	50	40920	551	1.1	3.3	642
7	75	27	69	52	40920	624	1.1	3.4	656
8					40920	#DIV/0!	#DIV/0	0.0	225
9					42920	#DIV/0!	#DIV/0	0.3	225
10					40920	#DIV/0!	#DIV/0	0.0	225
11					42920	#DIV/0!	#DIV/0!	0.2	225

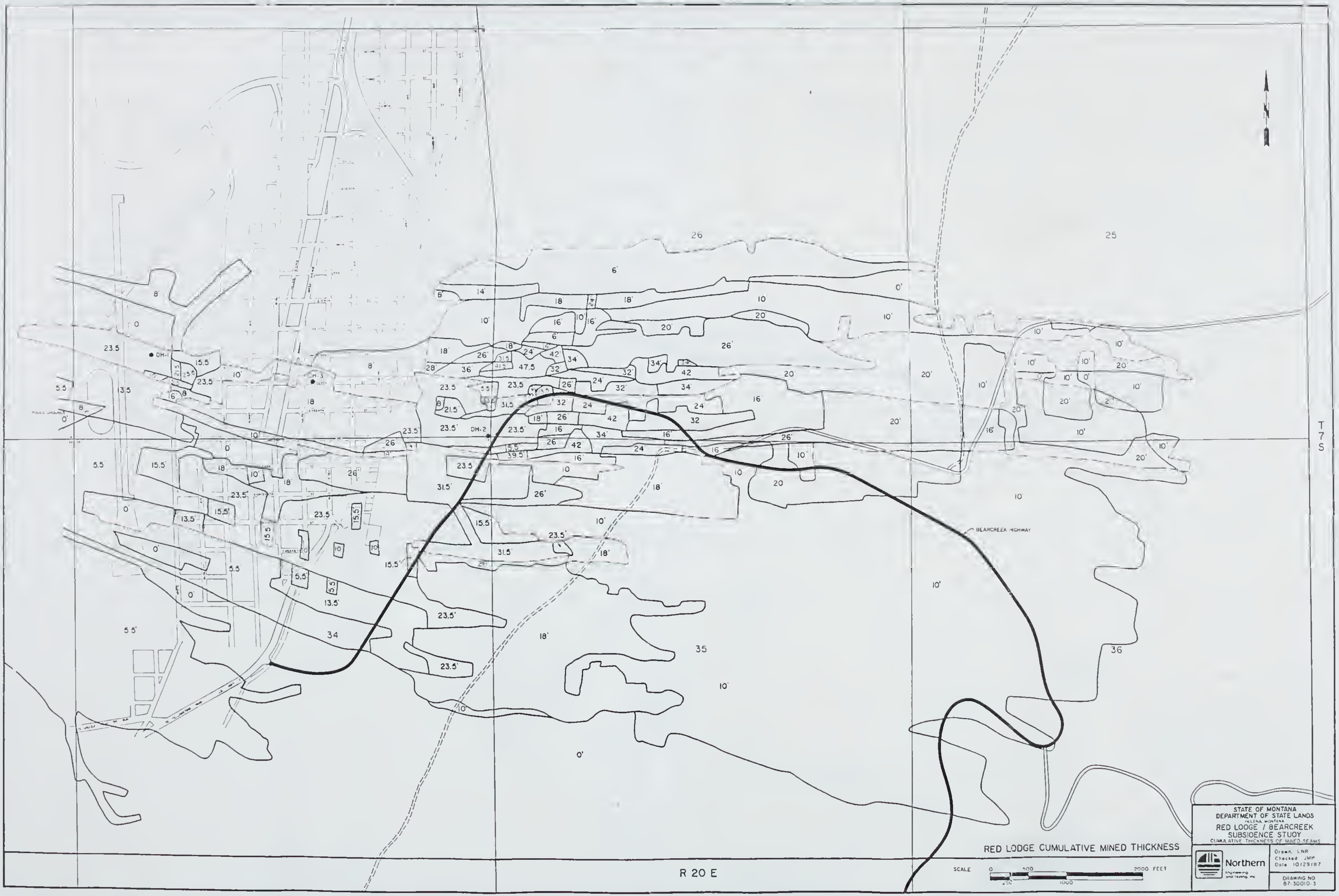
RED LODGE / BEARCREEK SUBSIDENCE STUDY
Roof Collapse Analysis

Problem Description: No. 3 Seam at DH-3
Room Size, Ft.= 35

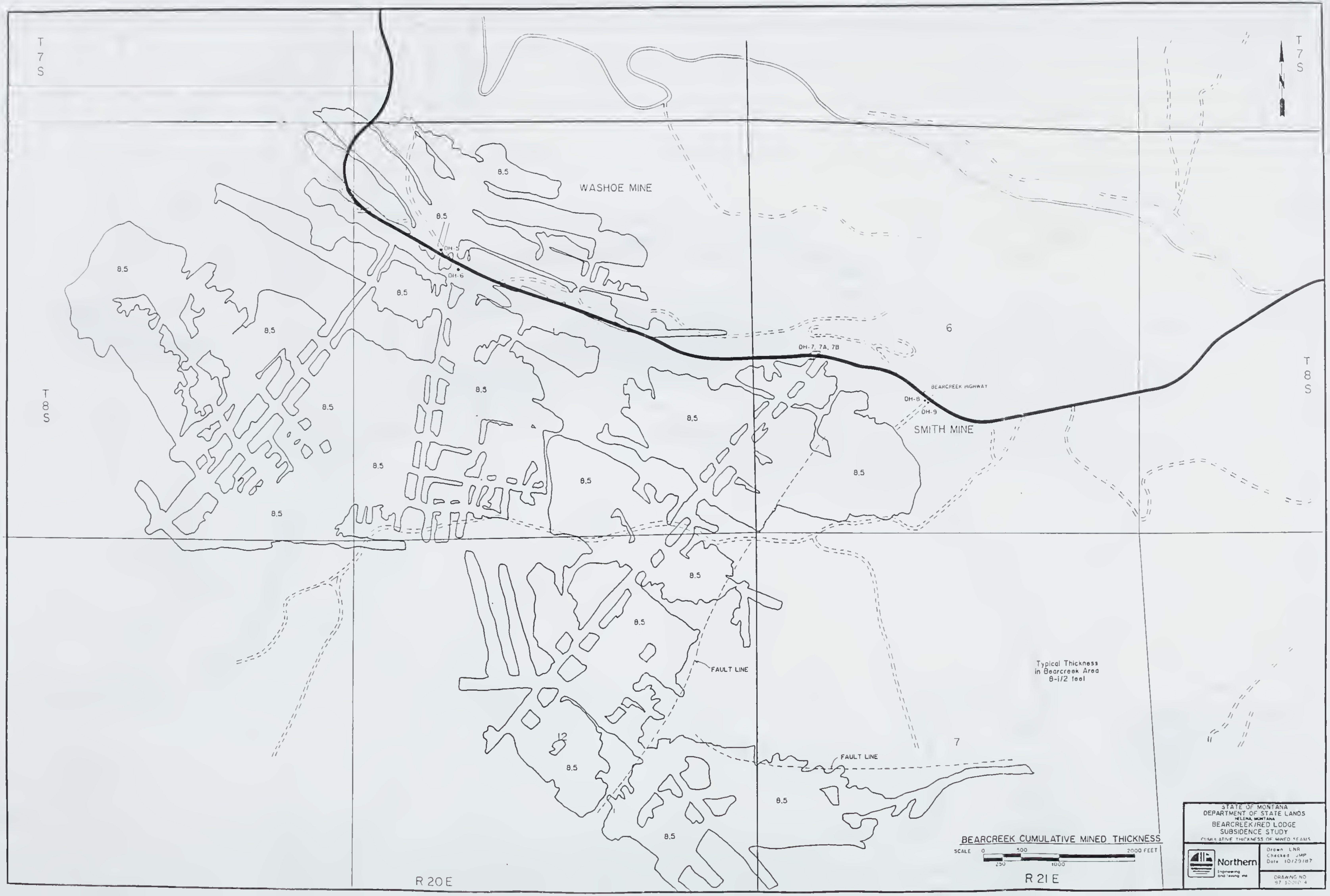
Layer No.	Unit Weight pcf	Layer Thickness Ft.	E psi	Tensile Strength psi	Individual Layer Deflection Ft.	F.S. Individual Layer Tensile Failure	F.S. Composite Layer Tensile Failure
1	64	223	[illegible]	2	[illegible]	3.2	#DIV/0!
2	53	182	4E+04	.75	4.[illegible]	53.2	35.8
3	93	5	4E+04	133	3.[illegible]	1.7	1122..
4					#DIV/0!	#DIV/0!	#DIV/0!


26
25
34
35
36
T 7 S
R 20 E
INSUFFICIENT DATA TO PROJECT CONTOURS OR SUBSIDENCE POTENTIAL
INSUFFICIENT DATA TO PROJECT CONTOURS OR SUBSIDENCE POTENTIAL
BEARCREEK HIGHWAY
NOT MINED
NOT MINED
DH-1
DH-2
DH-3
SEAM #4 1720
SEAM #3 1550
SEAM #4 1600
SEAM #3 1570
SEAM #4 1680
SEAM #4 1670
SEAM #4 1660
SEAM #4 1710
SEAM #4 1630
SOUTHERN LIMITS
SOUTHERN LIMITS
SOUTHERN LIMITS
Contour Interval = 50'
UPPER LIMIT - NO. 1-1/2 BED
UPPER LIMIT - NO. 2 BED
UPPER LIMIT - NO. 3 BED
UPPER LIMIT - NO. 4 BED
UPPER LIMIT - NO. 5 BED
UPPER LIMIT - NO. 6 BED
RED LODGE DEPTH OF COVER MAP
SCALE 0 250 500 1000 2000 FEET
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA MONTANA
RED LODGE / BEARCREEK
SUBSIDENCE STUDY
DEPTH OF COVER MAP
Northern
Engineering and Testing Inc
Drawn LNR
Checked JMP
Date 10/29/87
DRAWING NO
87-30010-1

T 7 S
T 8 S
WASHOE MINE
ENTRY TUNNEL
DH-5
SMITH MINE
BEARCREEK HIGHWAY
DH-7 /A /B
DH 8
DH 9
6
7
12
FAULT LINE
FAULT LINE
R 20 E
R 21 E
BEARCREEK DEPTH OF COVER MAP
SCALE 0 500 1000 2000 FEET
Countour Interval = 50'
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA, MONTANA
BEARCREEK/RED LODGE
SUBSIDENCE STUDY
DEPTH OF COVER MAP
Northern
Drawn LNR
Checked JMP
Date 10/29/87
DRAWING NO
87-30010 2



26
25
35
36
T 7 S
R 20 E
DH-1
DH-2
DH-3
BEARCREEK HIGHWAY
RED LODGE CUMULATIVE MINED THICKNESS
SCALE 0 500 2000 FEET 250 1000
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA, MONTANA
RED LODGE / BEARCREEK
SUBSIDENCE STUDY
CUMULATIVE THICKNESS OF MINED SEAMS
Northern
Engineering and Testing, Inc.
Drawn LNR
Checked JMP
Date 10/29/87
DRAWING NO
87-3001D-3



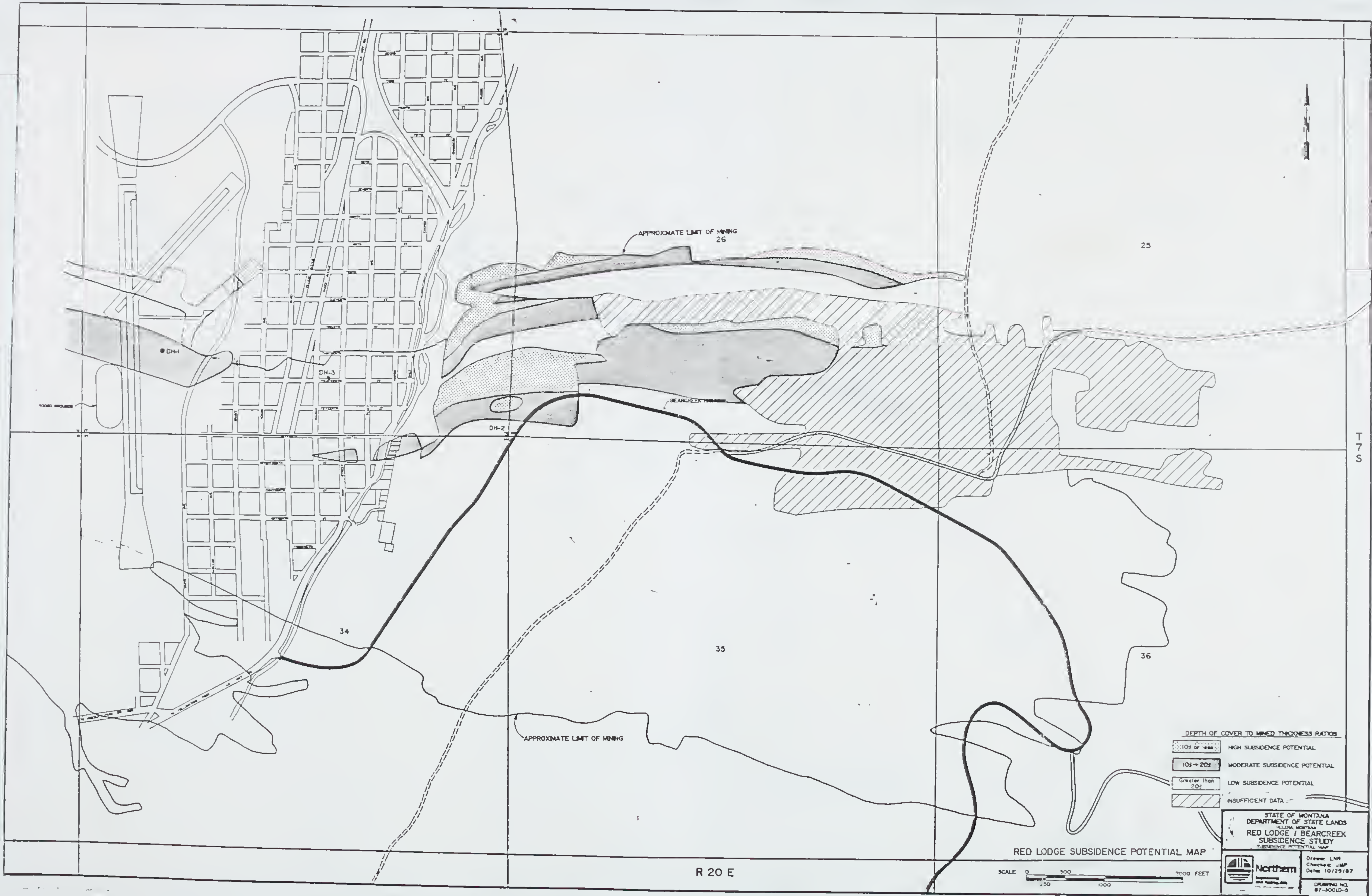
BEARCREEK CUMULATIVE MINED THICKNESS

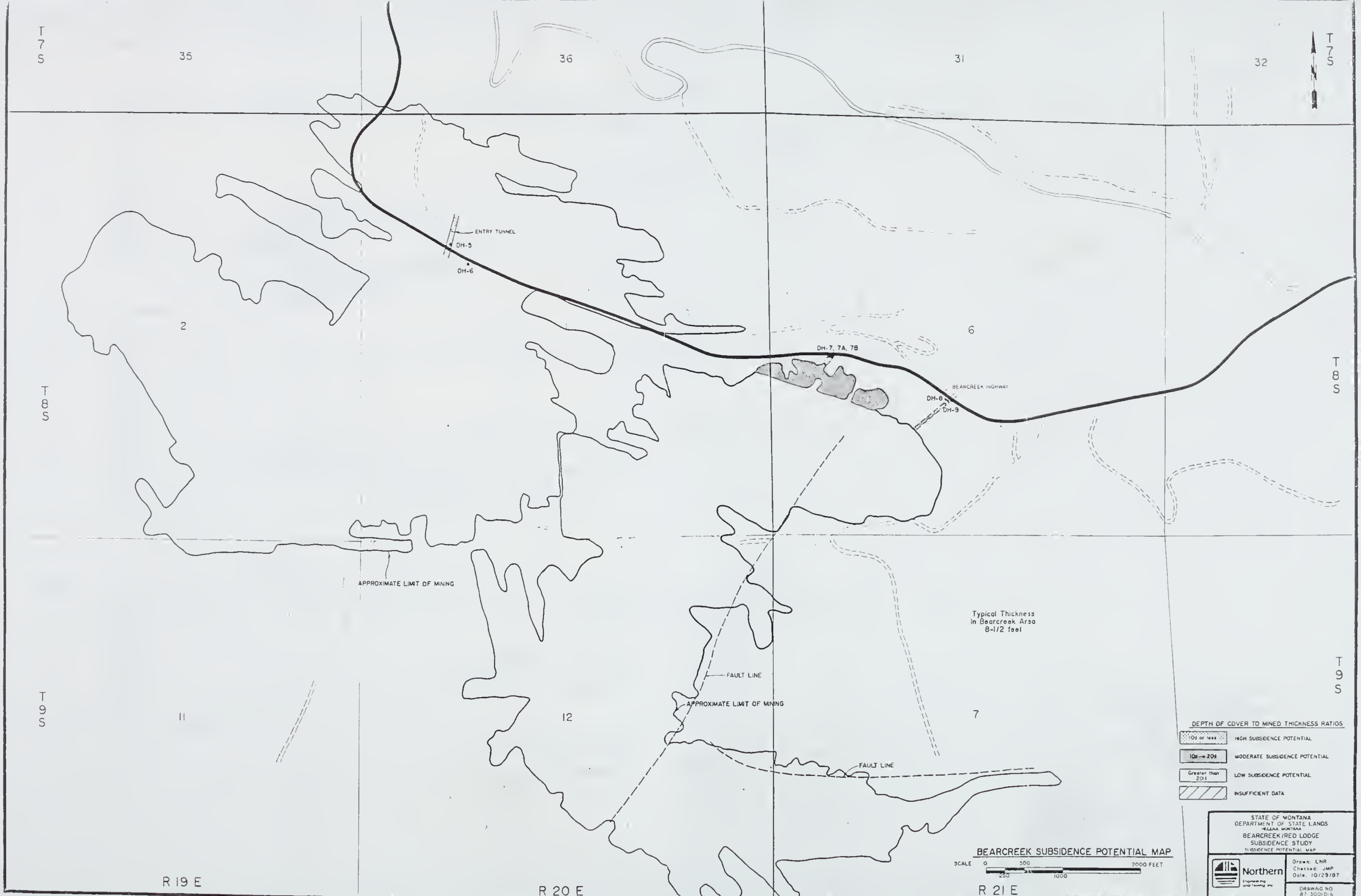
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA, MONTANA
BEARCREEK/RED LODGE
SUBSIDENCE STUDY
CUMULATIVE THICKNESS OF MINED SEAMS

Northern Engineering and Testing, Inc.

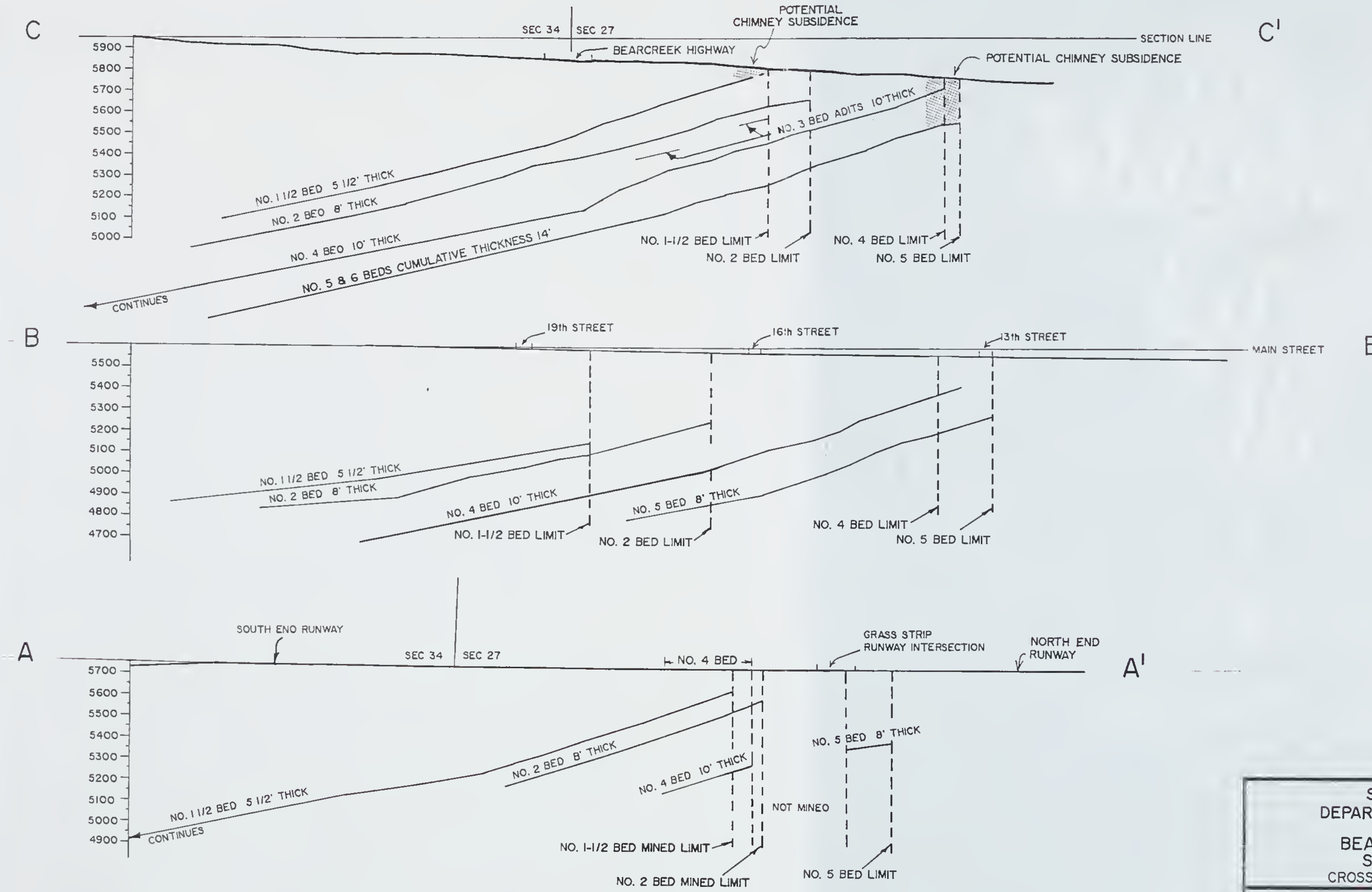
Drawn LNR
Checked JMP
Date 10/29/87

DRAWING NO
97 30010 4


APPROXIMATE LIMIT OF MINING
26
25
DH-1
DH-3
DH-2
RODEO GROUNDS
BEARCREEK HIGHWAY
T 7 S
34
35
36
APPROXIMATE LIMIT OF MINING
R 20 E
DEPTH OF COVER TO MINED THICKNESS RATIOS
10:1 or less
HIGH SUBSIDENCE POTENTIAL
10:1 → 20:1
MODERATE SUBSIDENCE POTENTIAL
Greater than 20:1
LOW SUBSIDENCE POTENTIAL
INSUFFICIENT DATA
RED LODGE SUBSIDENCE POTENTIAL MAP
SCALE 0 500 2000 FEET
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA, MONTANA
RED LODGE / BEARCREEK
SUBSIDENCE STUDY
SUBSIDENCE POTENTIAL MAP
Northern
Drawn: LNR
Checked: JMP
Date: 10/29/87
DRAWING NO.
87-300LD-3



T 7 S
35
36
31
32
T 7 S
ENTRY TUNNEL
DH-5
DH-6
2
6
DH-7, 7A, 7B
BEARCREEK HIGHWAY
DH-8
DH-9
T 8 S
T 8 S
APPROXIMATE LIMIT OF MINING
Typical Thickness
in Bearcreek Area
8-1/2 feet
FAULT LINE
APPROXIMATE LIMIT OF MINING
FAULT LINE
T 9 S
T 9 S
11
12
7
DEPTH OF COVER TO MINED THICKNESS RATIOS
10:1 or less
HIGH SUBSIDENCE POTENTIAL
10:1 → 20:1
MODERATE SUBSIDENCE POTENTIAL
Greater than 20:1
LOW SUBSIDENCE POTENTIAL
INSUFFICIENT DATA
BEARCREEK SUBSIDENCE POTENTIAL MAP
SCALE 0 500 2000 FEET
250 1000
STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA MONTANA
BEARCREEK/RED LODGE
SUBSIDENCE STUDY
SUBSIDENCE POTENTIAL MAP
Northern
Engineering and Testing Inc
Drawn: LNR
Checked: JMP
Date. 10/29/87
DRAWING NO
87-3001D-6
R 19 E
R 20 E
R 21 E



STATE OF MONTANA
DEPARTMENT OF STATE LANDS
HELENA, MONTANA

BEARCREEK/RED LODGE SUBSIDENCE STUDY
CROSS SECTIONS OF MINE LIMITS

Northern Engineering and Testing, Inc

Drawn: LNR
Checked: JMP
Scale: 1" = 500'
Date: 10/29/87

DRAWING NO.
87-3001.D-7